A Scalable Approach to User-session-based Testing of Web Applications through Concept Analysis

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Web-based Applications

- Web pages on server, clients access pages
  - Example: e-commerce applications
- Characteristics
  - Short time to market
  - Extensive use
  - High reliability, continuous availability
  - Changing user profiles
- User-session data
  - Client URL requests and name-value pairs (data)

Challenges of User-session-based Testing

- Leverage user-session data as test cases applicable in beta/maintenance testing phases
  - Elbaum et al. (2003)
- Manage/replay large set of user sessions
- Existing test suite reduction non-scalable
  - Harrold et al. (1993)

Contributions

- View user sessions as use-cases
- Apply concept analysis for test suite reduction
- Perform incremental test suite update
- Automate the testing framework [ICSM 04]
- Evaluate cost effectiveness
  - Test suite size
  - Program coverage
  - Fault detection

⇒ Scalable user-session-based testing

Concept Analysis

Mathematical technique for clustering objects that have common discrete attributes

Input – theory

Set of objects, O

Set of attributes, A

Binary relation, $R \subseteq O \times A$

Example Concept Analysis – Input

Objects: **{airplane, boat, rollerskates, unicycle}**

Attributes: **{wheel(s), over80mph, passengers, wear, engine}**

Binary Relation Table:

attributes

objects

	wheel(s)	over80mph	passengers	wear	engine
airplane	●	●	●		●
boat		●	●		●
rollerskates	●			●	
unicycle	●				

Concept Analysis - Output

- Identifies concepts for a given tuple (O, A, R)
- A *concept* is a tuple

$$t = (O_i, A_j)$$

- Concepts form a partial order defined as

$$(O_1, A_1) \leq (O_2, A_2) \; iff \; O_1 \subseteq O_2$$

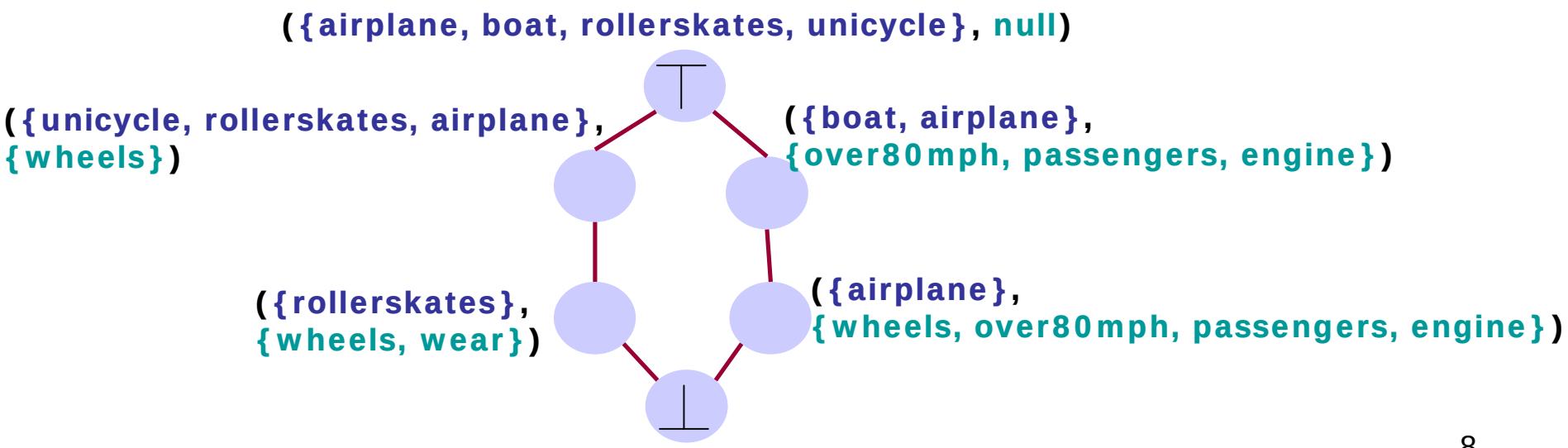
$$(O_1, A_1) \leq (O_2, A_2) \; iff \; A_1 \supseteq A_2$$

Example Concept Analysis Output

attributes

objects

	wheels	over80mph	passengers	wear	engine
airplane	●	●	●		●
boat		●	●		●
rollerskates	●			●	
unicycle	●				



Concept Analysis for Web Testing

attributes (URLs)

objects

	GD	GR	GL	PL	GS	GB	GM
us1	●	●	●				
us2	●	●	●		●		●
us3	●	●	●	●	●		
us4	●	●	●		●	●	
us5	●	●	●				
us6	●	●	●	●	●	●	

- Set of objects
  - User sessions, *s*, denoted by IP addresses
- Set of attributes
  - URLs, *u*
- Binary relation table
  - A pair *(s, u)* is in the relation table if *s* requests *u*

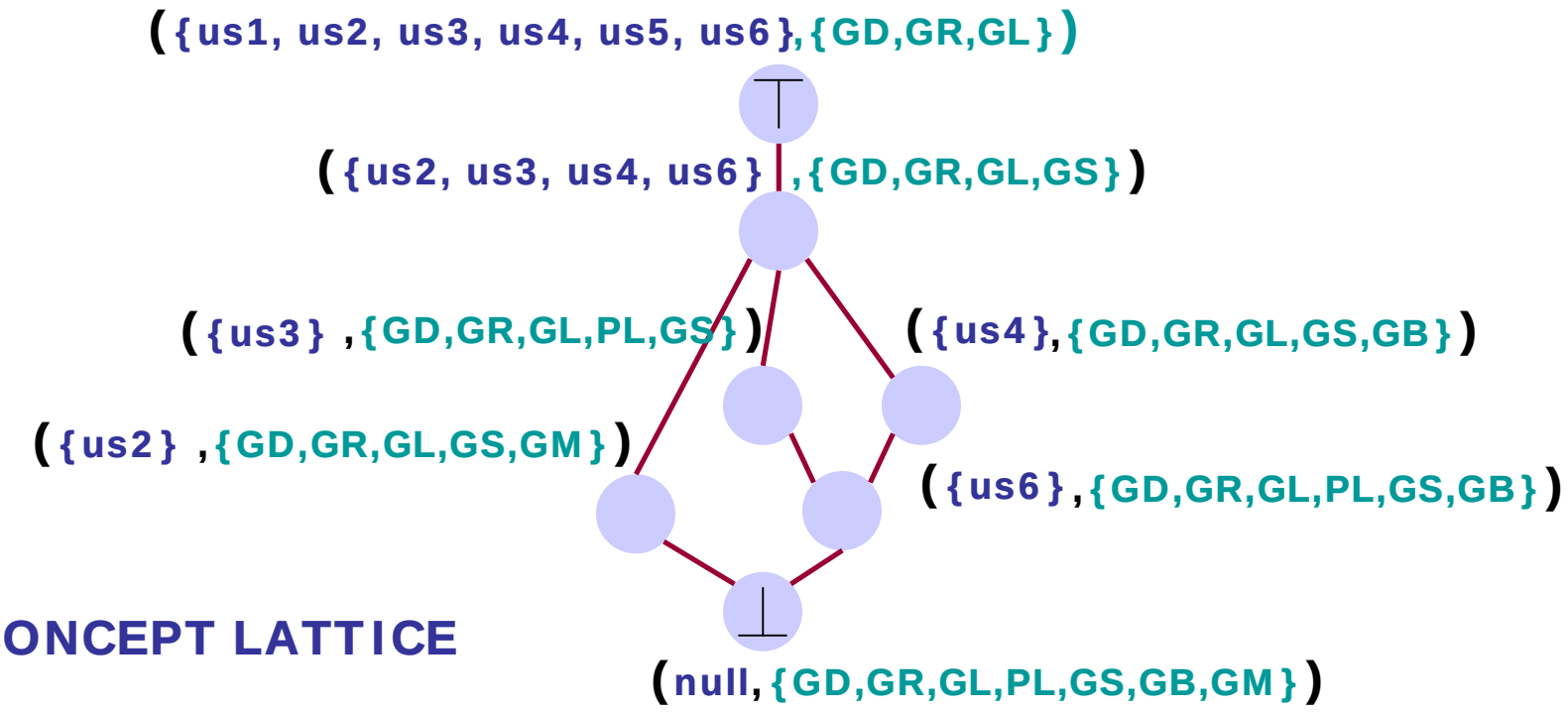
RELATION TABLE

attributes (URLs)

objects

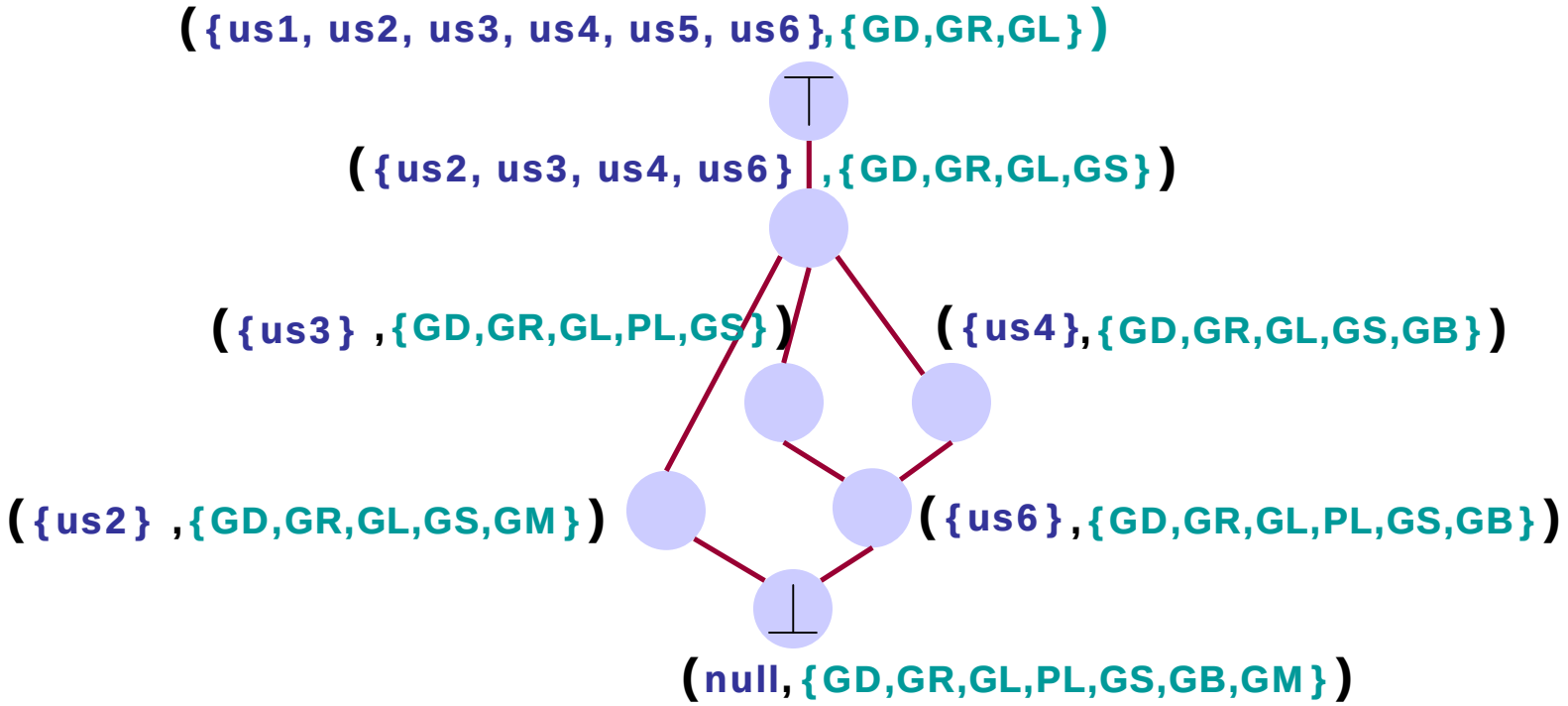
	GD	GR	GL	PL	GS	GB	GM
us1	●	●	●				
us2	●	●	●		●		●
us3	●	●	●	●	●		
us4	●	●	●		●	●	
us5	●	●	●				
us6	●	●	●	●	●	●	

CONCEPT LATTICE

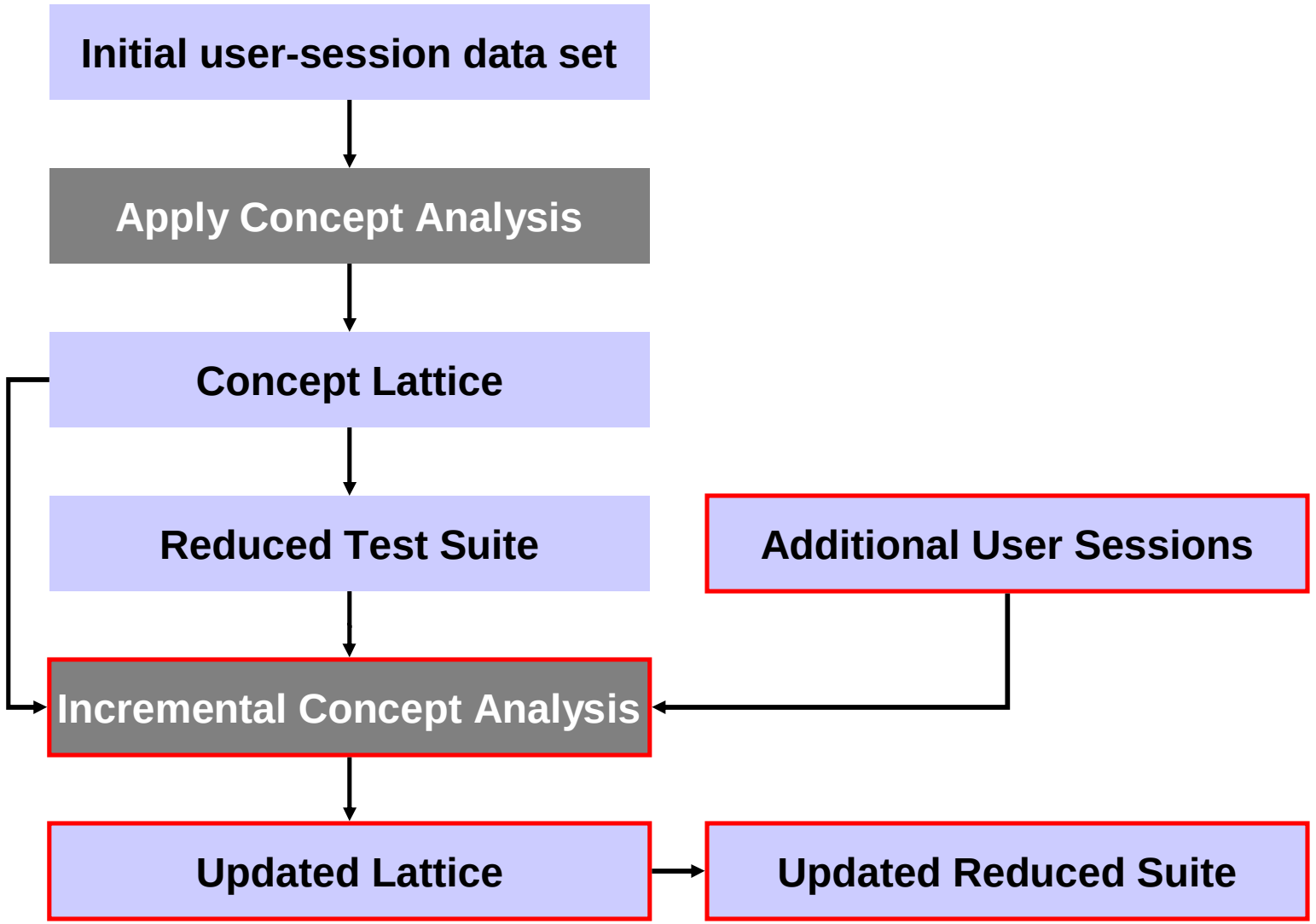


Test Suite Reduction

- Exploit lattice's hierarchical use-case clustering [WODA 04]
- Heuristic for test suite reduction
  - Smallest set of user sessions that will cover all URLs of the application executed by original suite



Incremental Test Suite Update



Incremental Test Suite Update

- Utilize Godin et al.'s incremental algorithm
  - Create new nodes/edges
  - Modify existing nodes/edges
- **Key insight: Scalability**

  Existing internal nodes do not sink to bottom
  - Test cases not maintained for internal nodes

Incremental Test Suite Update

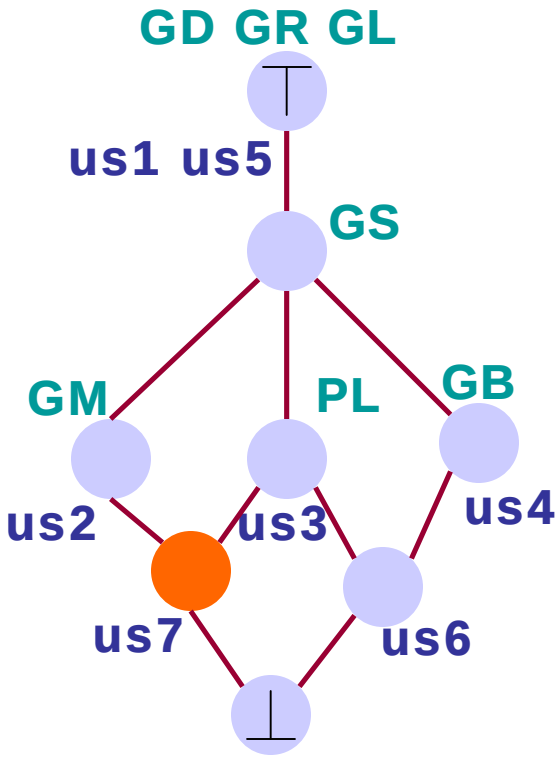
RELATION TABLE

attributes (URLs)

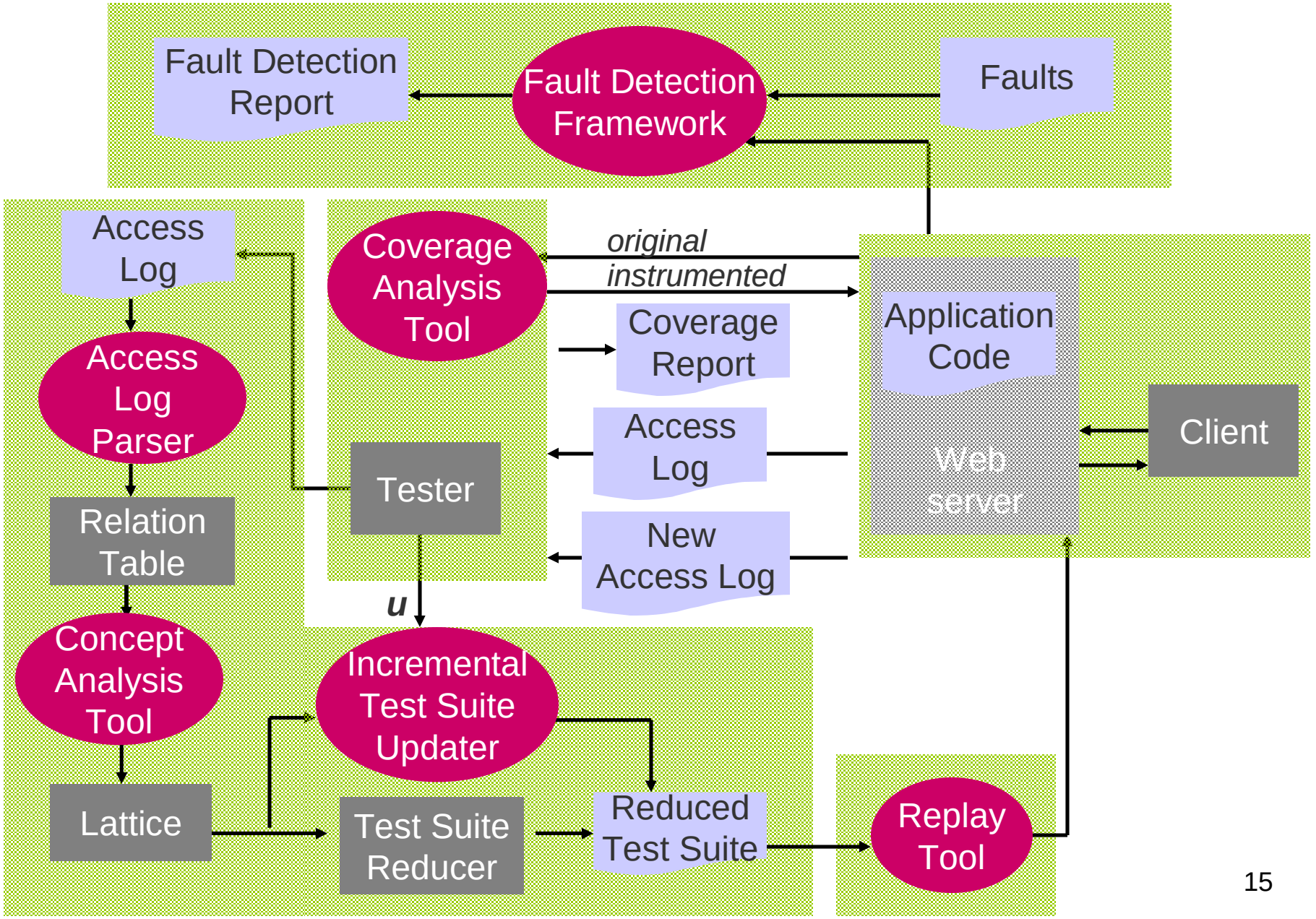
objects

	GD	GR	GL	PL	GS	GB	GM
us1	●	●	●				
us2	●	●	●		●		●
us3	●	●	●	●	●		
us4	●	●	●		●	●	
us5	●	●	●				
us6	●	●	●	●	●	●	
us7	●	●	●	●	●		●

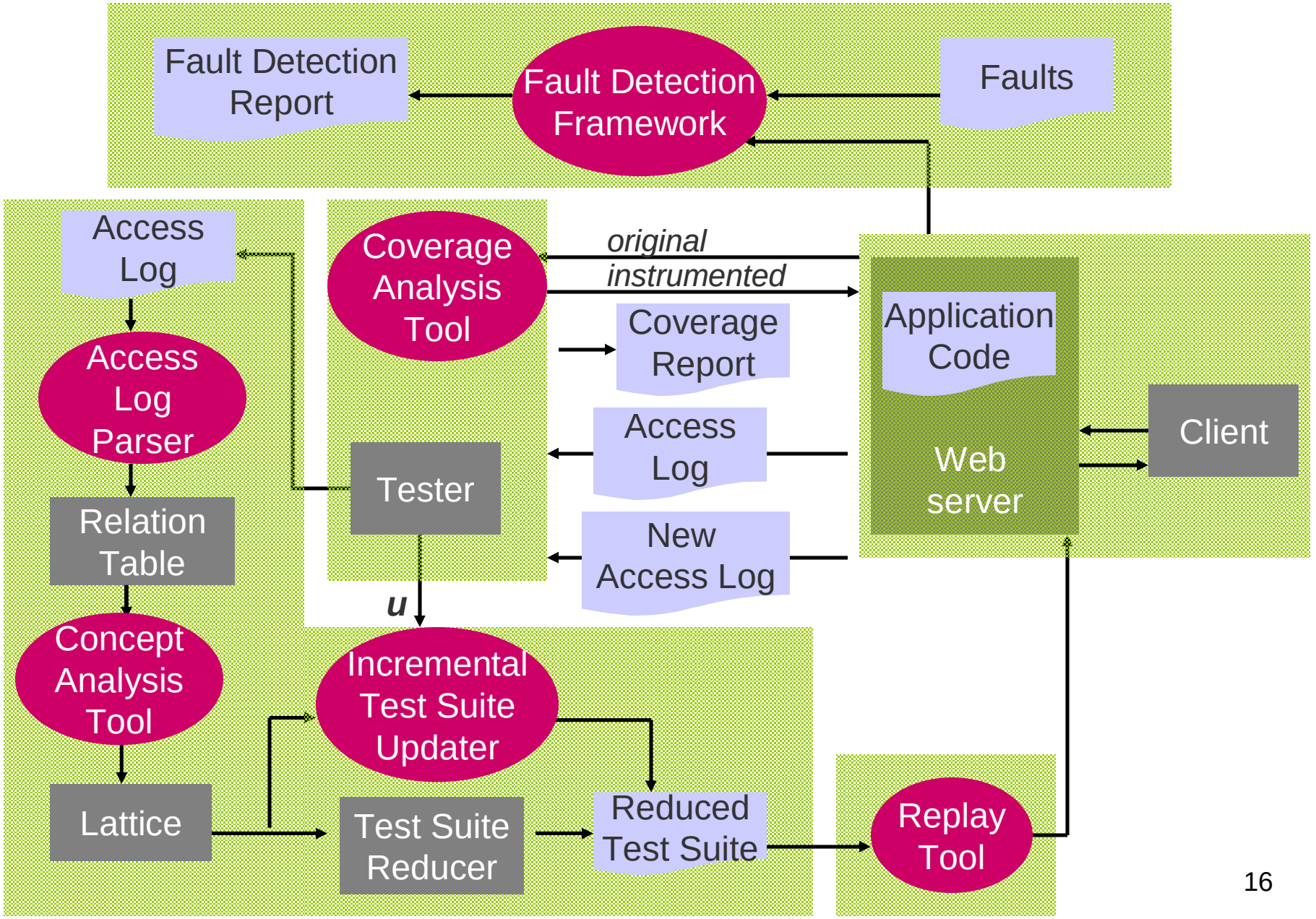
SPARSE UPDATED LATTICE



Web Testing Framework



Web Testing Framework



Experimental Evaluation

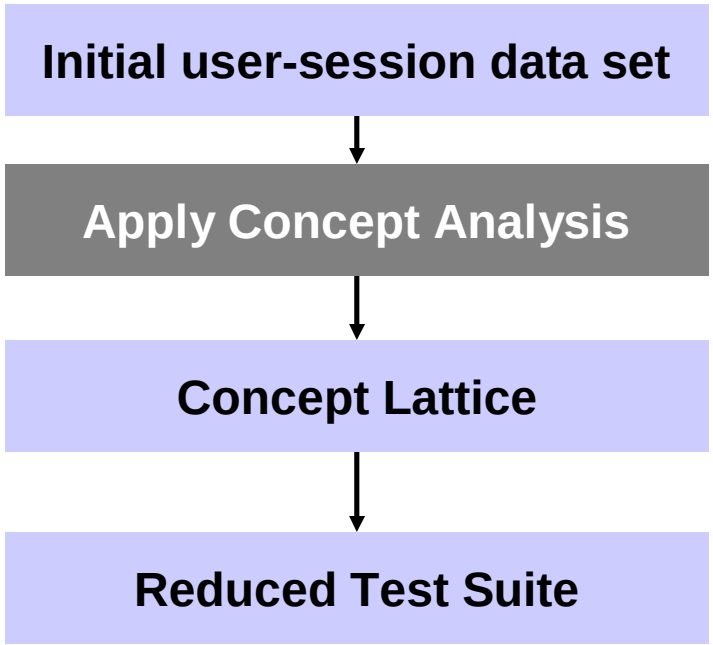
- Evaluate test suite reduction achieved through concept analysis
  - Test suite size
  - Replay and oracle time
- Cost-effectiveness of incremental vs. batch
- Program coverage analysis of reduced suite
- Fault detection capability of reduced suite

Study Setup

- Bookstore application
  - 9748 lines of code
  - 385 methods
  - 11 classes
- JSP front-end, MySQL backend
- Resin web server
- 123 user sessions
- 40 faults

Test Suite Reduction

Methodology



Metrics

- Test suite size
- Replay time
- Oracle time

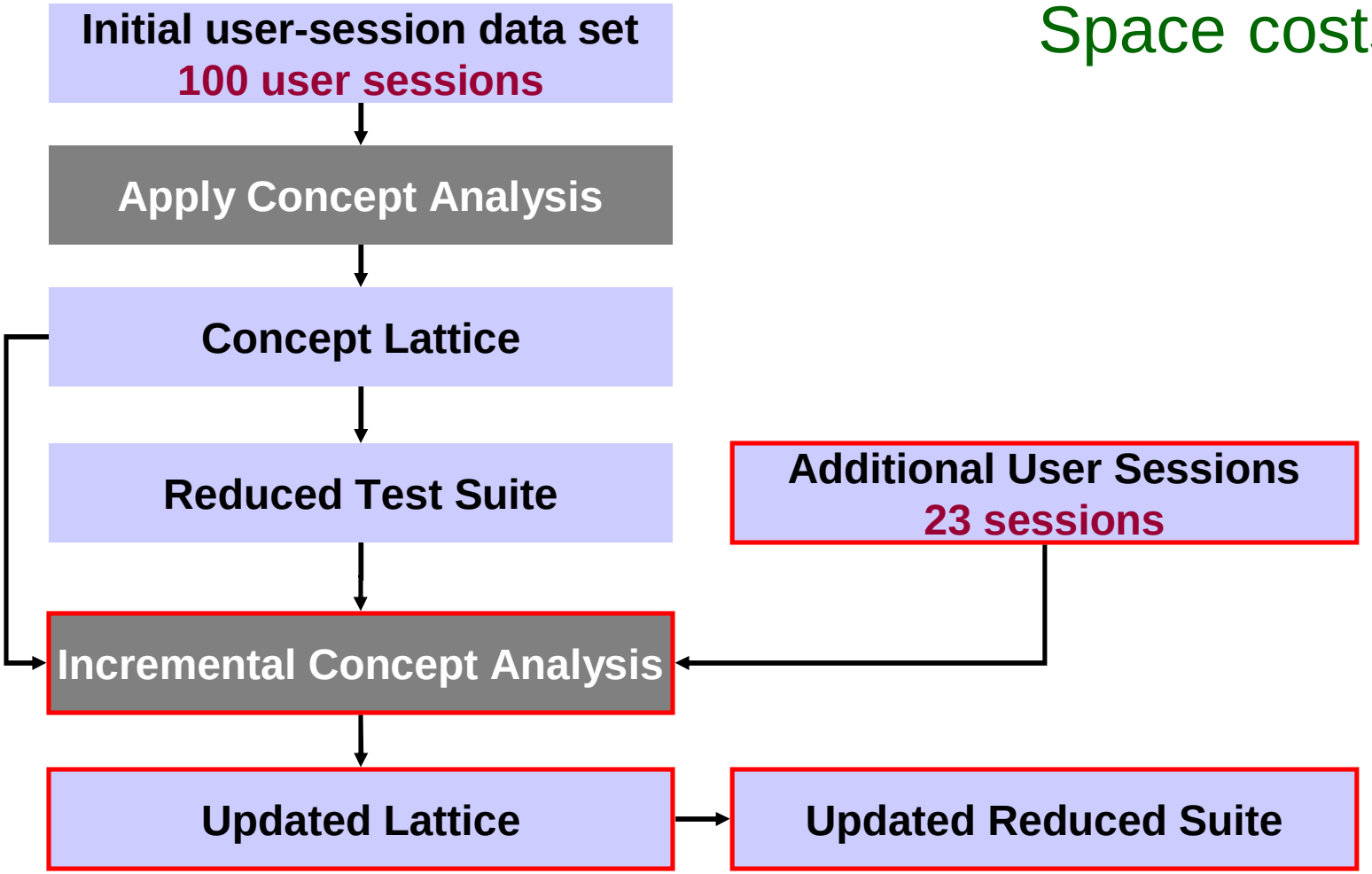
Test Suite Reduction Results

Metrics	Original Suite	Reduced Suite	Reduction
Test suite size	123	15	87.8%
Replay time	16m56s	4m22s	74.2%
Oracle time	25m30s	5m17s	79.3%

- The large percent reduction in test suite size results in reduction in replay and oracle time
- Considerable savings in replay and oracle when compared to time for suite reduction, 19s [ICSM 04]

Incremental versus Batch

Methodology



Metric

Space costs

Incremental versus Batch Results

Metric	Original Suite	Reduced Suite	Reduction
Space	4.3MB	1MB	76.7%

- **Scalability:** Incremental test suite update saves space by not maintaining original suite of sessions
- Perform incremental update overnight with day's collection of user sessions to produce updated suite

Program Coverage

Methodology

- Use *Clover* for coverage analysis
- Restore database state before replay
- Use *wget* for replaying user sessions
- Pass cookies and post-data information

Metrics

- Statement and method coverage

Program Coverage Results

Metrics	Original Suite	Reduced Suite	Preserved Coverage
Statement Coverage	60.3%	58%	96.2%
Method Coverage	53.2%	53.2%	100%

- Reduced suite preserves program coverage obtained from original suite
- Low loss of program coverage due to
  - Heuristic that covers all URLs of the application
  - Reduction with low loss of use case representation [WODA 04]

Fault Detection Study

Methodology

- Manually seed 40 faults in application
- Replay user sessions through
  - Correct version of application to generate expected result
  - Faulty versions of application to generate actual result
- *Diff* the expected and actual results

Metric

- Number of faults detected

Fault Detection Study Results

Metrics	Original Suite	Reduced Suite	Preserved
Faults Detected	87.5%	70%	80%

- Reduced suite maintains fault detection capability
- Investigating additional test suite reduction heuristics

Related Work

- Concept Analysis in Software Engineering
  - Recovering components, Eisenbarth et al. (2003)
  - Debugging temporal specifications, Ammons et al. (2003)
- Reducing Test Suites
  - Harrold et al. (1993)
  - Offutt et al. (1995)
- Web Testing
  - Link and form testers
  - Liu et al. (2000)
  - Ricca and Tonella (2001)
  - Di Lucca et al. (2002)
  - Elbaum et al. (2003)

Conclusions

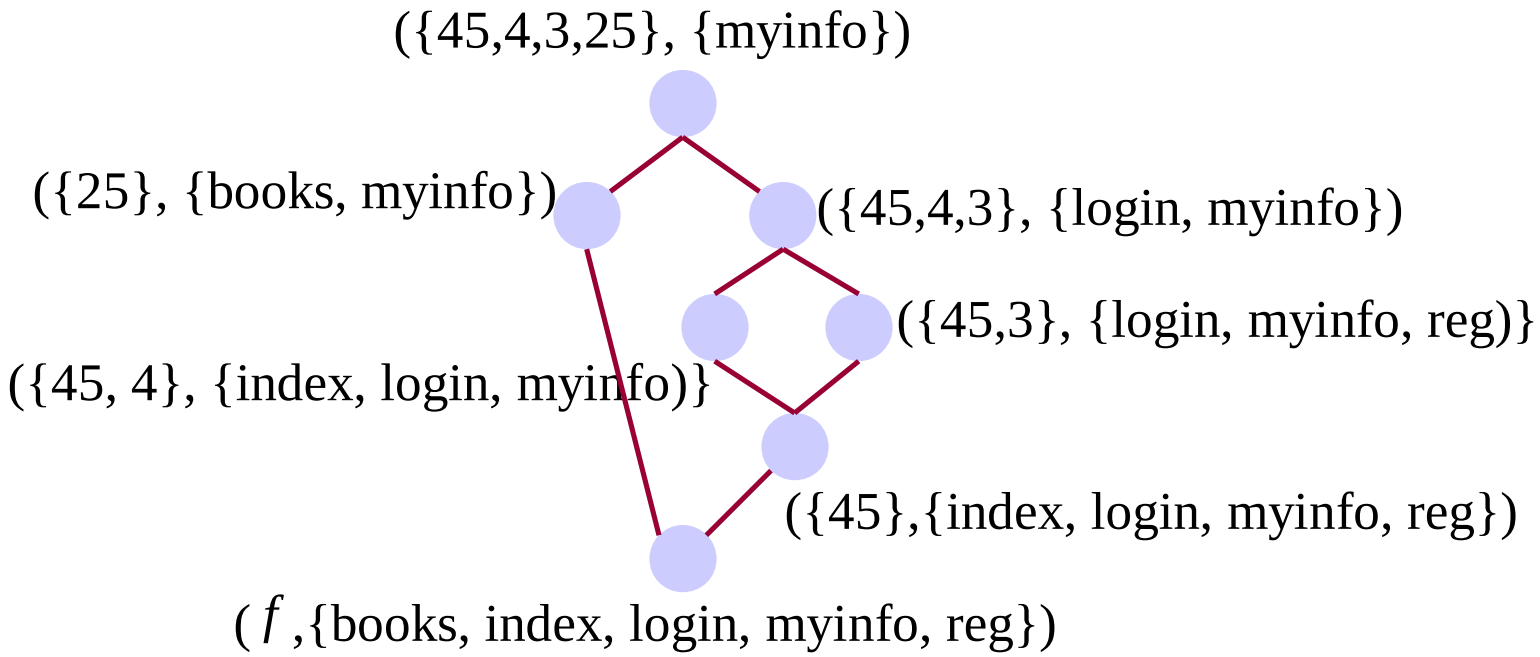
- Test suite reduction by concept analysis
  - Achieves large reduction in test suite size
  - Saves oracle and replay time
- Incremental test suite update presents scalable approach to user-session-based testing
- Reduced test suite preserves program coverage and fault detection capability

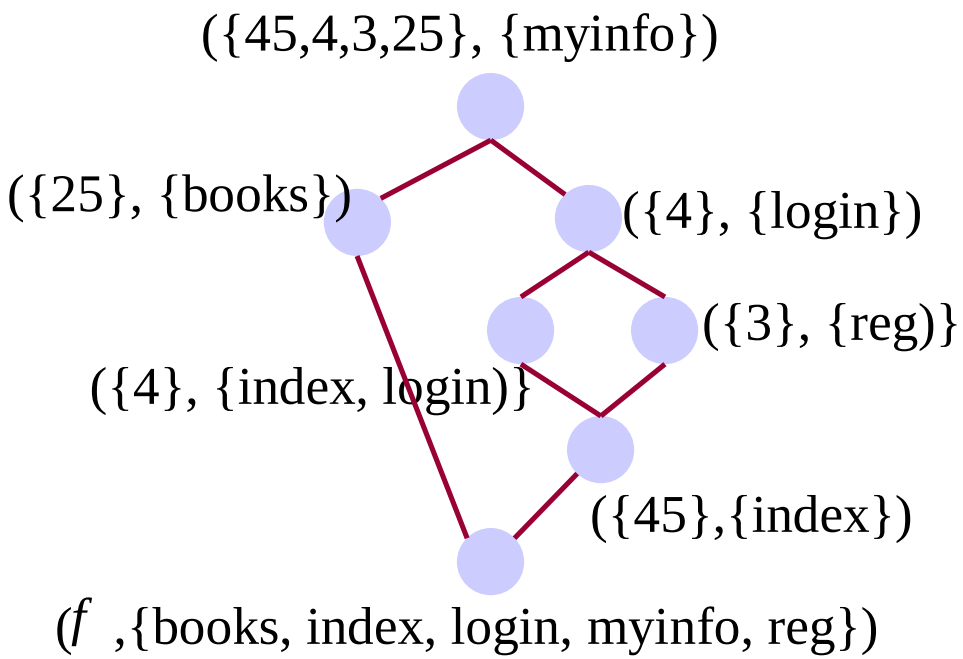
Future Work

- More significant empirical evaluation
- Extend incremental concept analysis to handle program evolution
- Alternate heuristics for test suite reduction

Relation Table and Concept Lattice

	index	login	reg	books	myinfo
45	●	●	●		●
3		●	●		●
4	●	●			●
25				●	●

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