Conformance of Implementation to a Security Architecture

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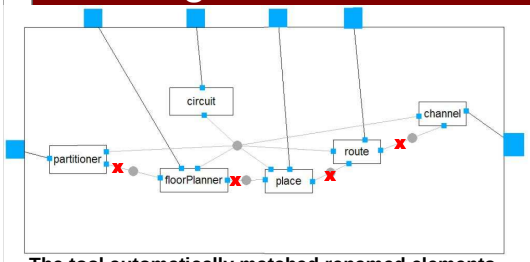
An architectural approach to security

- The security architecture of a system shows its runtime components, and how those components communicate, with various security invariants on where authentication occurs or untrusted input is validated, etc. It matches how experts think about security, vs. a purely code-based strategy.
- However, the Achilles heel of a security architecture is the lack of any enforced or checked architectural conformance between the actual code and the intended security architecture of the system.
- We should be able to trust the architecture to reflect the actual implementation: an incorrect model can be worse than no model at all, as it may mislead us into an incorrect understanding of the system's security.

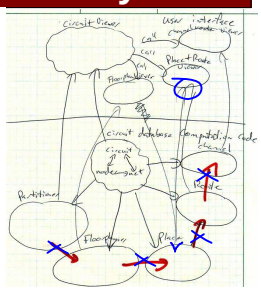
Enforcing architectural conformance

- Enforcement of architectural intent at the **programming language level** using a small number of annotations at architectural boundaries;
- Automated abstraction of an **instance-based hierarchical runtime** architectural view from **annotated** code;
- **Semi-automated incremental synchronization** between the implementation-level view and the conceptual-level view to detect and correct divergences.

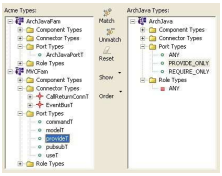
Checking conformance: case study 1



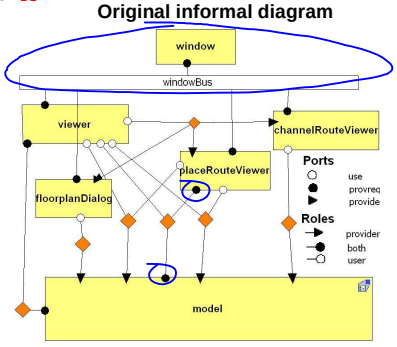
The tool automatically matched renamed elements and detected extra connectors marked with X

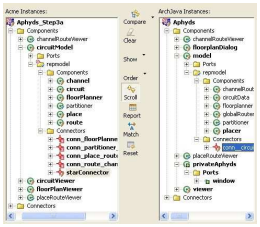


Original informal diagram



Matching two incompatible type structures at two different levels of abstraction



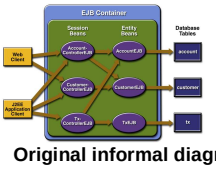


The tool detects structural differences:
- **Match (✓),**
- **Insert (+),**
- **Delete (-),**
- **Rename (✎)**

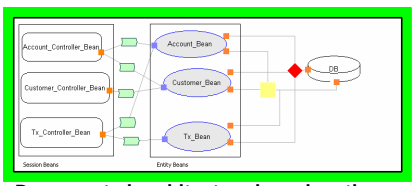
The synchronized diagram reveals a missing sub-system and a callback

Automatically matching architectural instances using structural comparison

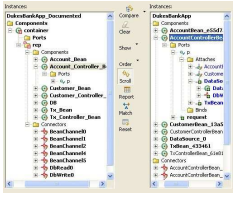
Checking conformance: case study 2



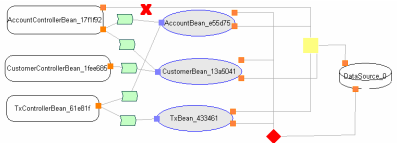
Original informal diagram



Documented architecture based on the informal diagram



Automatically matching architectural instances



The as-built architecture: the connection marked with X is a violation of the documented architecture and of the EJB specification!

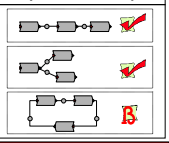
Synchronizing architectural views

Detect structural differences:
- No Unique Identifiers
- Detect Renames
- Detect Hierarchical Moves
- Support Manual Overrides
- Type Information Optional
- Disconnected/Stateless Operation
- Detect inserts and deletes

Key Idea: Using the **tree-hierarchy** in hierarchical views gives **scalability** over general **graph matching.**

Detect additional violations:
- Uncover additional non-structural violations by enriching the up-to-date architectural model with
- Architectural types and styles
- Constraints (general predicates)

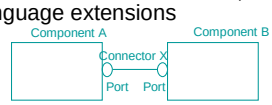
Example: no **cycles** allowed in a system following the **pipe-and-filter** architectural style



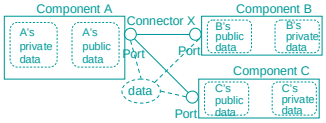
Specifying architectural intent in code

Initial attempts: extend the underlying language

- **ArchJava:** enforce the ***control flow*** architectural structure, with language extensions



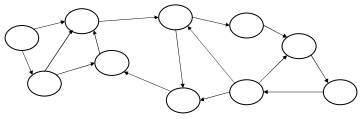
- **AliasJava:** annotations to describe the data sharing architecture, i.e., data:
  - **Confined** within component
  - **Passed** linearly from one component to another
  - **Shared temporarily** or **persistently**

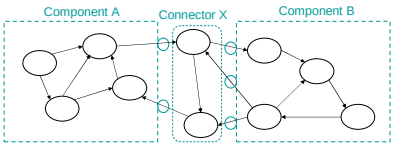


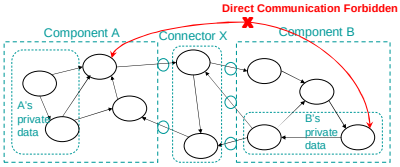
- **Case studies:** several studies were conducted on non-trivial systems to evaluate the usability of ArchJava and AliasJava.

Current research: impose architectural structure on arbitrary object graphs

- Use annotations instead of extensions
- Statically approximate runtime graph
- Add hierarchy using ownership



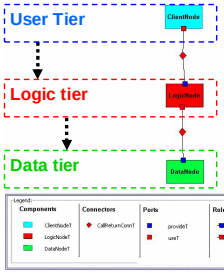




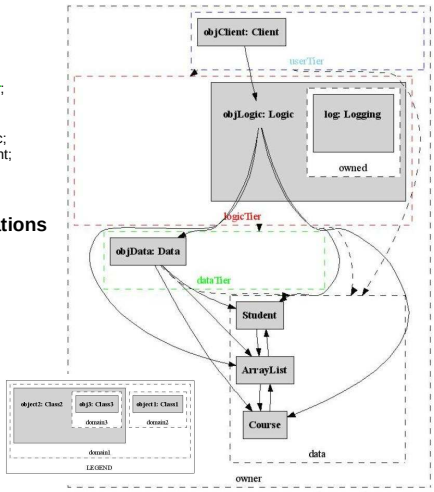
Abstracting runtime views from code

```
public class Main
{
  domain data;
  domain userTier, logicTier, dataTier;

  link userTier -> logicTier, logicTier -> dataTier;

  private dataTier Data<data> objData;
  private logicTier Logic<dataTier, data> objLogic;
  private userTier Client<logicTier, data> objClient;

  ....
}
```

Java program + AliasJava annotations



Architect's diagram showing components and connectors



Having view extracted from annotated code can better match how experts think about security, vs. a purely code-based strategy.

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