Improving System Dependability by Enforcing Architectural Intent

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Designing Dependability

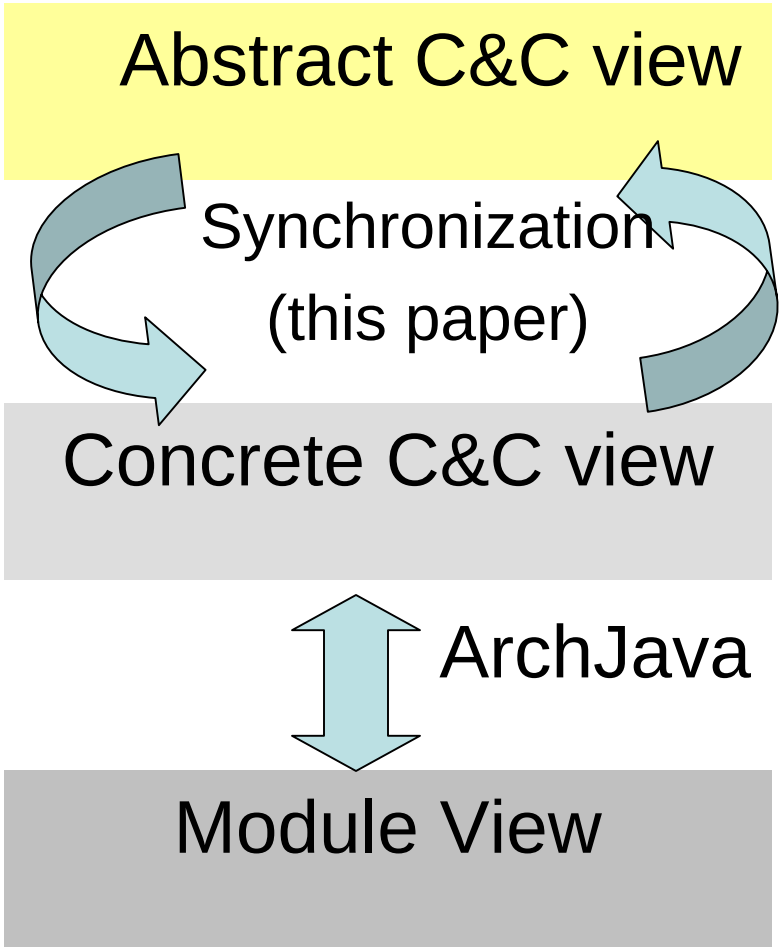
- Dependability analyses
  - Performance, reliability, fault-tolerance…
- Many architectural description languages, reasoning techniques
  - Examples: Rapide, Wright, Meta-H

Delivering Dependability

- Designed dependability achieved only if implementation conforms to design
- Implementation violations of architectural intent
  - Architectural structure
  - Architectural types and styles
- Ideally:
  - Architects work at appropriate level of abstraction
  - Design is faithful abstraction of implementation

Our Approach: Synchronize Abstract and Concrete C&C Views

- Abstract C&C view
  - Architect's design view
  - Problem-specific
  - May elide information
  - Example: Acme
- Concrete C&C view
  - Actual communication between implementation components
  - Example: ArchJava



Relating Conceptual Views to Implementation-Level Views

- Match Architectural structure
  - Inserted, deleted, renamed, moved elements
  - Do not rely on unique identifiers
  - Do not require names to match
- Match Architectural types and styles
- Lightweight, scalable, semi-automated, incremental

Bridging the Gap

- Matching Types (and Styles)
- Matching Structure

Matching Type Structures between Abstract and Concrete C&C Views

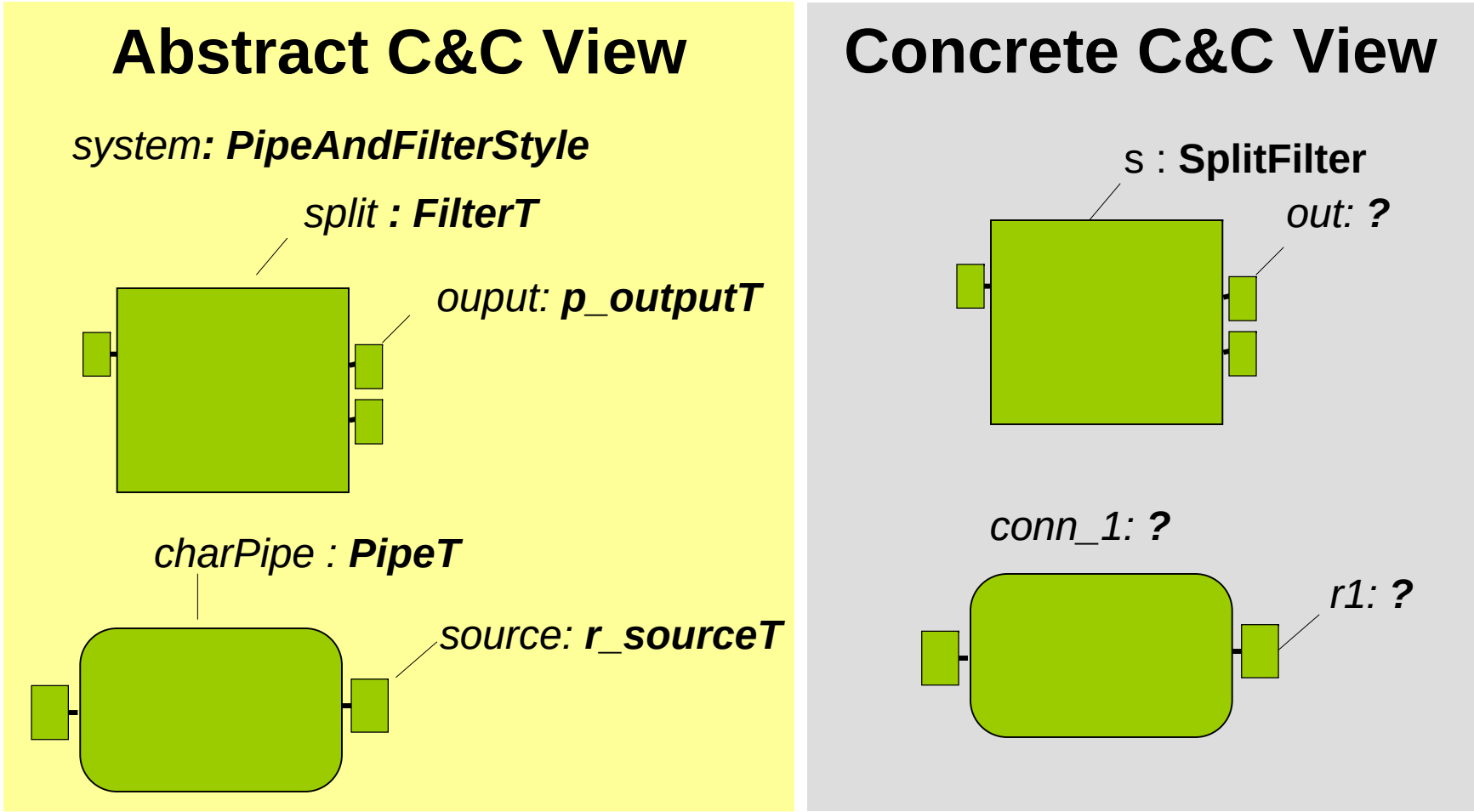
Acme Types

- Predicate-based type system
- Types = abstract logical predicates
- Architectural Style
  - Constraints (invariants or heuristics)
- Interfaces optional
  - Properties on ports

ArchJava Types

- Conventional type system
- Types = concrete interfaces
  - provided and required functionality
- Some types not first-class
  - Port types, role types..

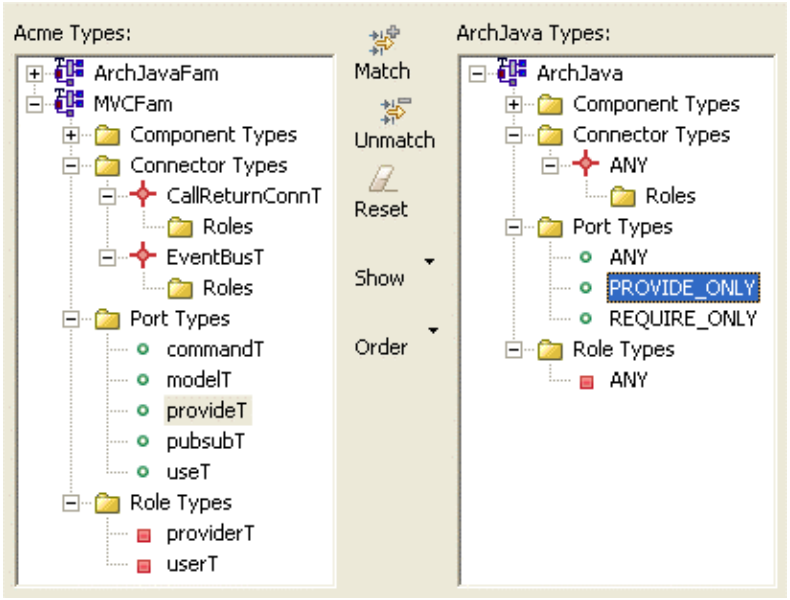
Matching Type Structures



1. First-class types missing in ArchJava for connectors, ports, roles
2. Acme types at higher level of abstraction

Matching Styles and Types

- Match explicit types if available
- Assign types to instances when no explicit type
- Special wildcards
- Infer types when possible
  - Using style information



Structural Differences

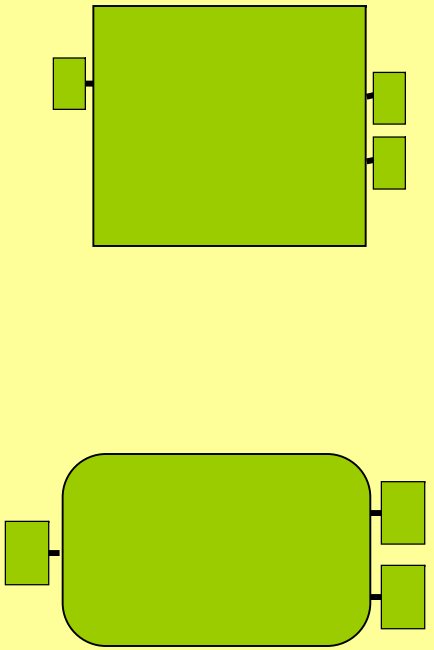
- Incidental renames
- Independent evolution
  - May forget to update other representation
- Design & Implementation
  - Different structures may be appropriate
    - E.g. hide representation inside a new component

- Types of differences
  - Renames
  - Inserts
  - Deletes
  - Moves
- Detection important for maintaining design properties

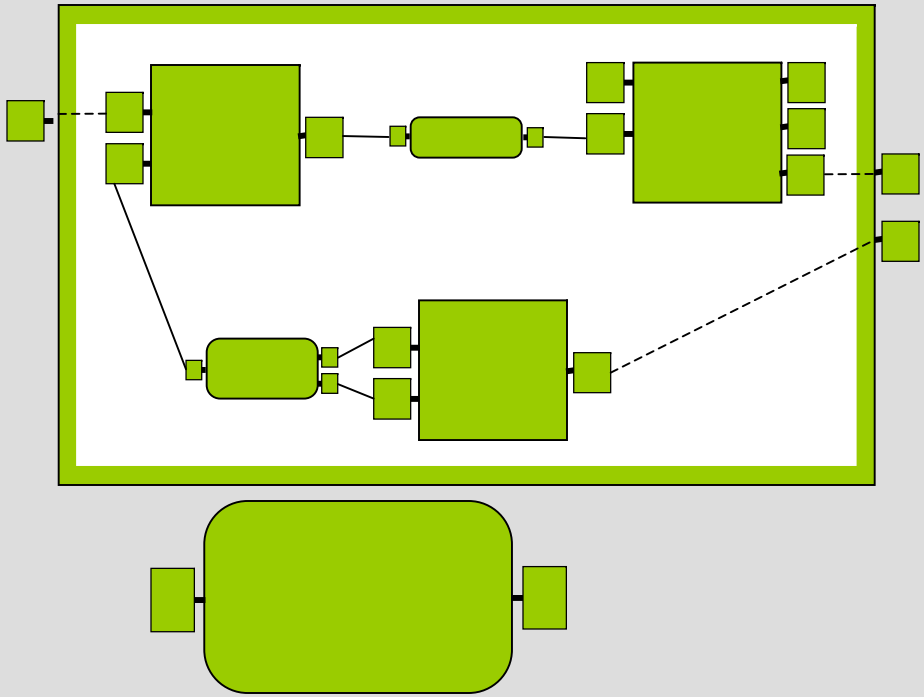
Strategy: Automated detection of differences

Insert/Delete Differences

Abstract C&C View

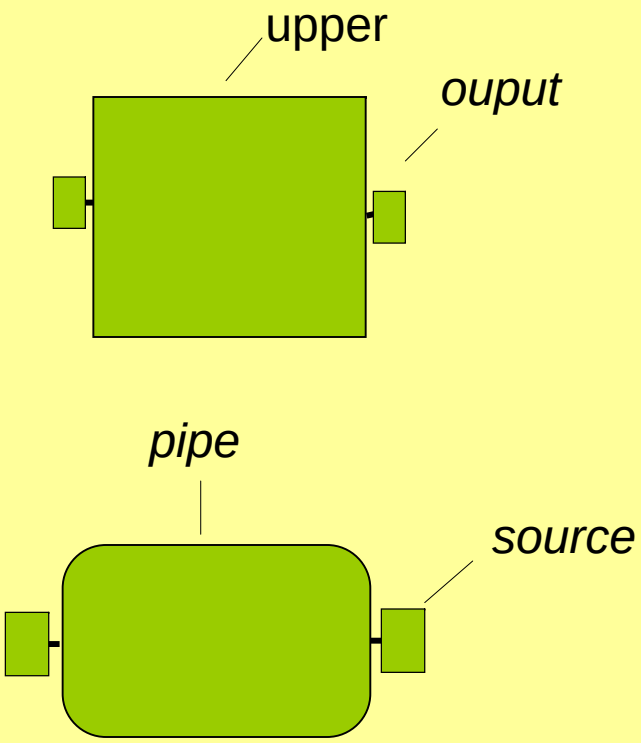


Concrete C&C View

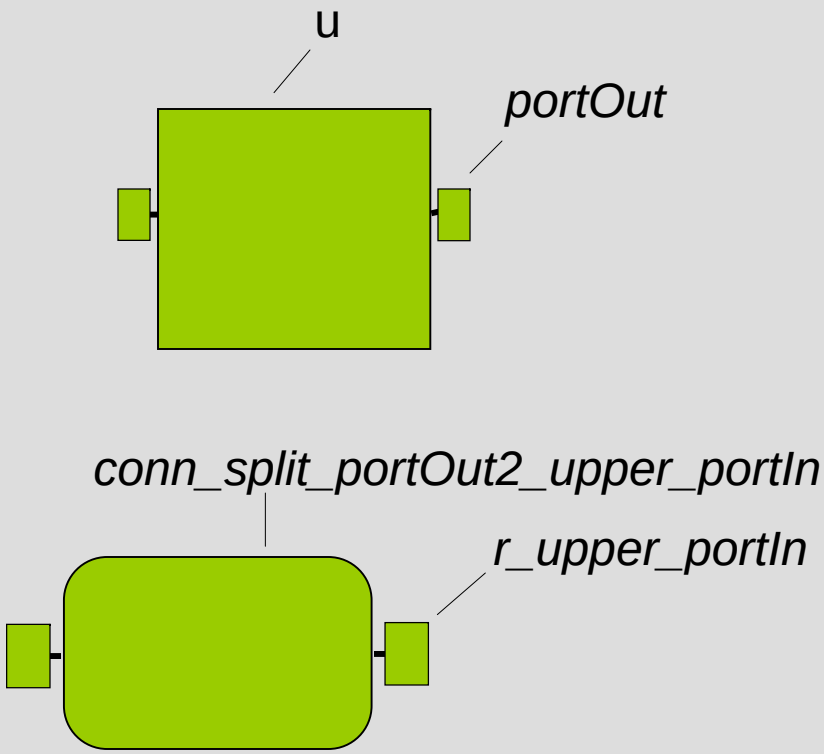


Naming Differences

Abstract C&C View

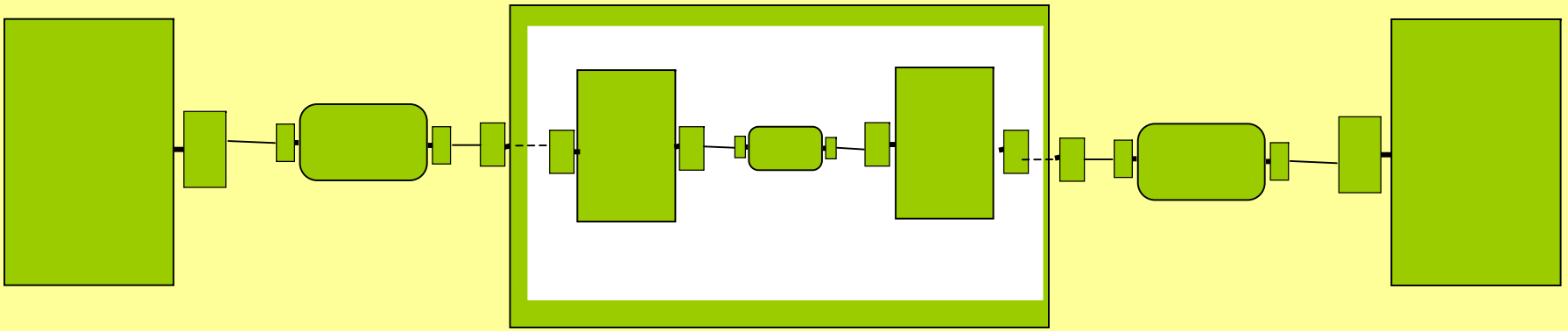


Concrete C&C View

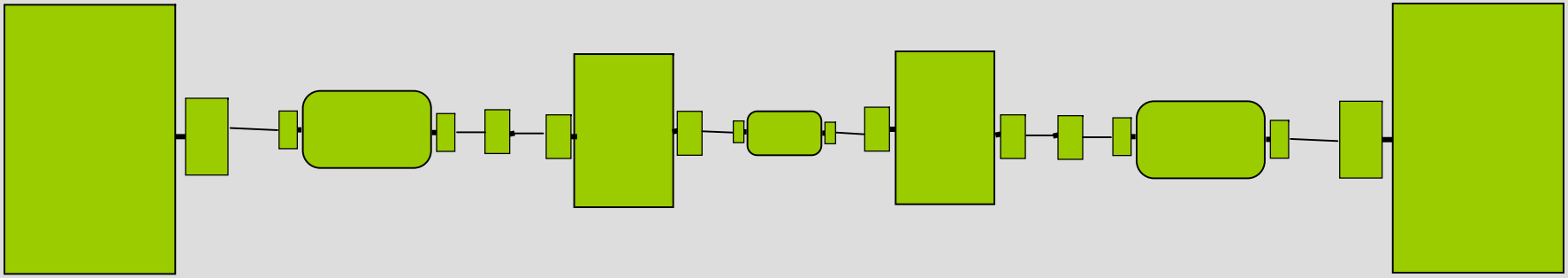


Move Differences

Abstract C&C View

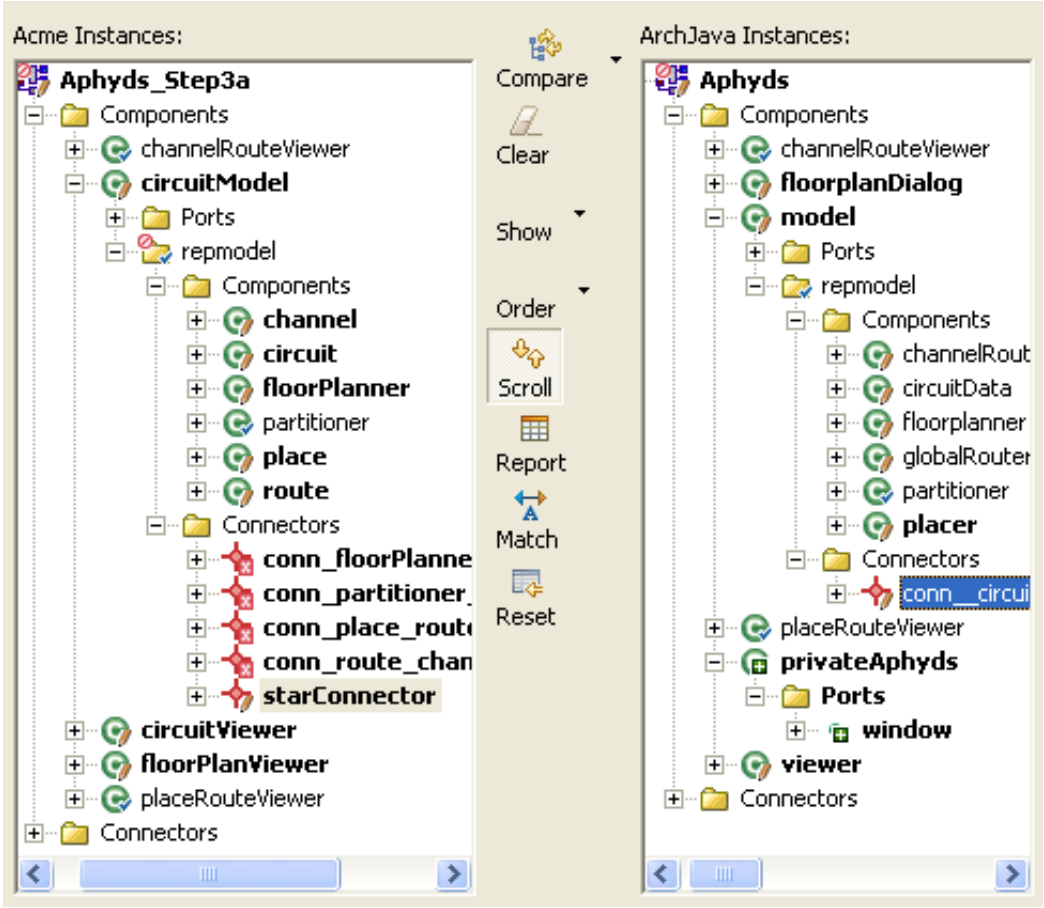


Concrete C&C View



Matching Architectural Structure

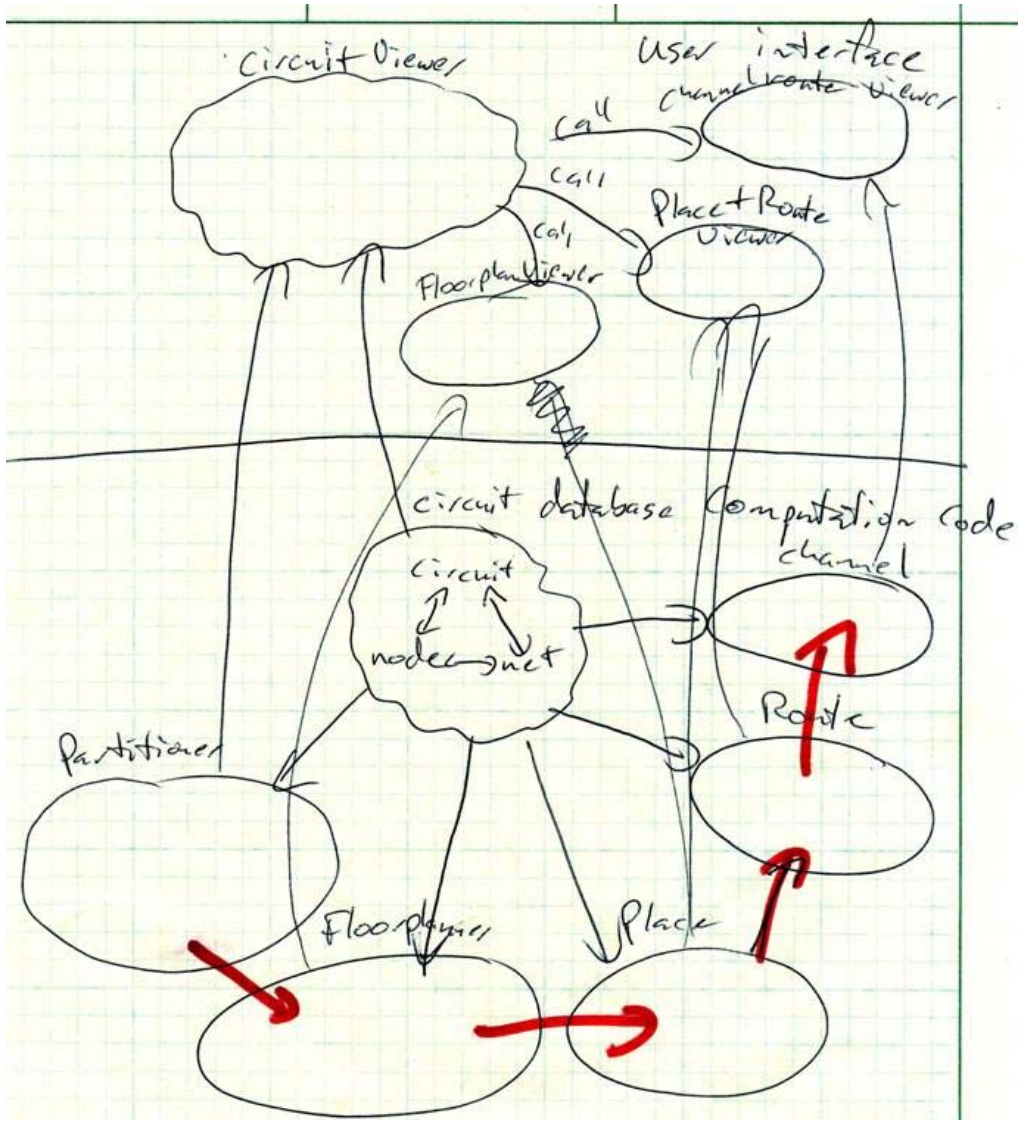
- Detect
  - Match
  - Insert
  - Delete
  - Rename
  - Move

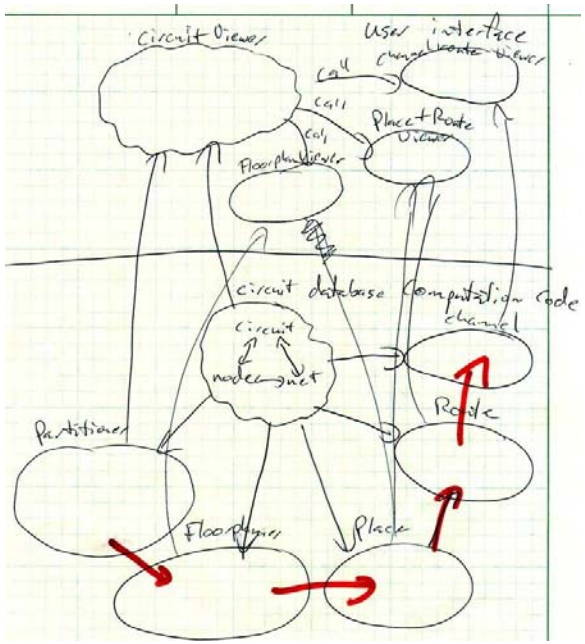


- Automated Tree-to-Tree Correction
  - Unordered attributed labeled trees

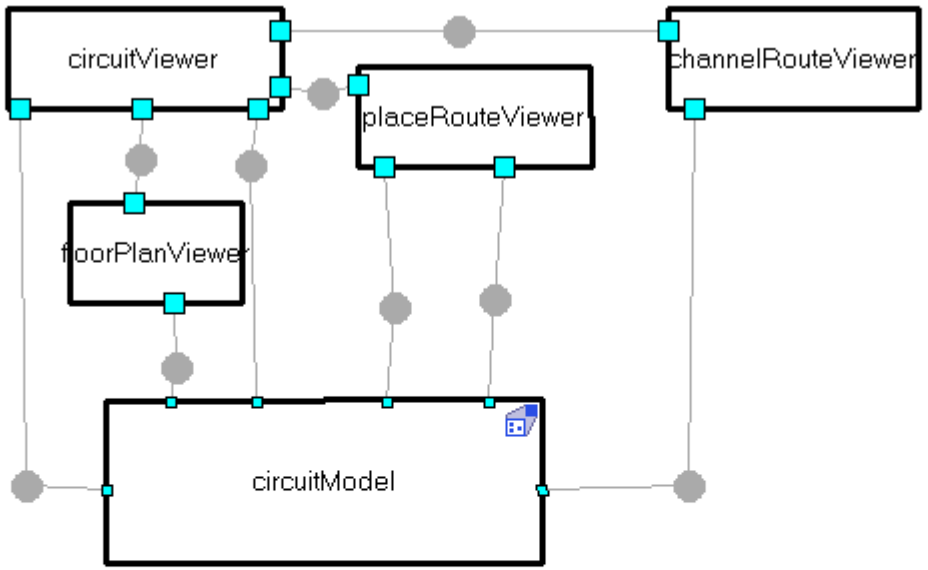
Extended Example

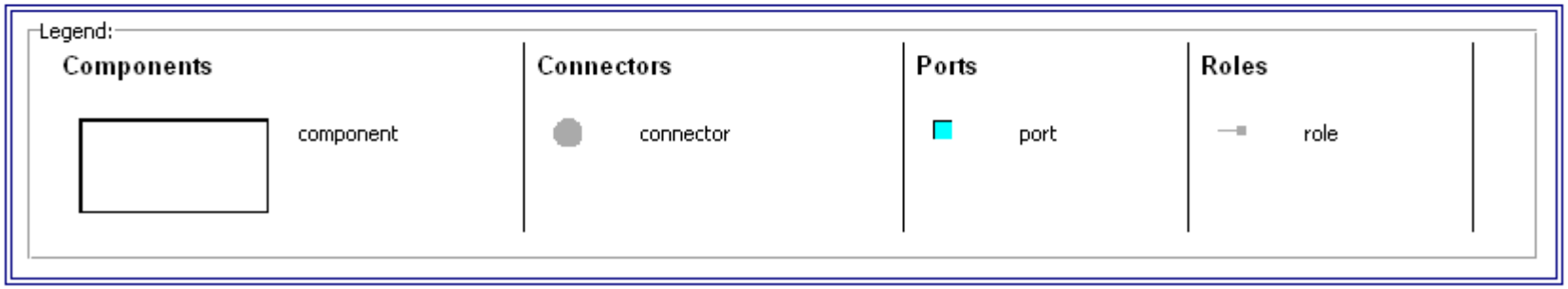
- ArchJava architecture consisting of
  - Over 20 components, 80 ports, several subsystems
- Re-engineered from Java application
  - Over 8 KSLOC
  - See [ACN02] for details

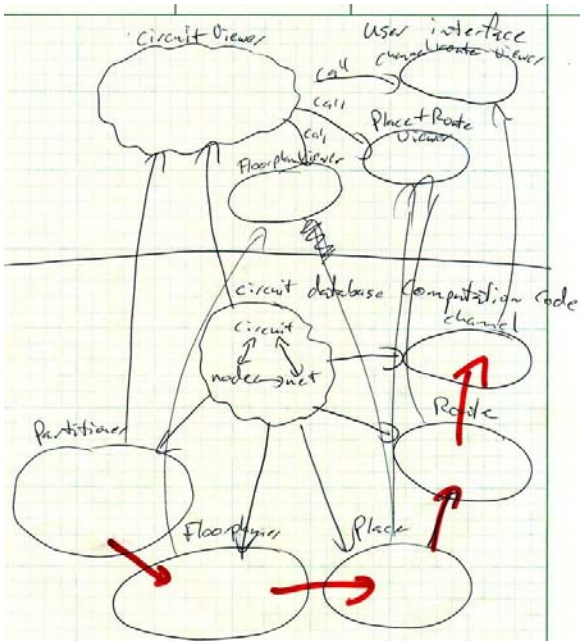




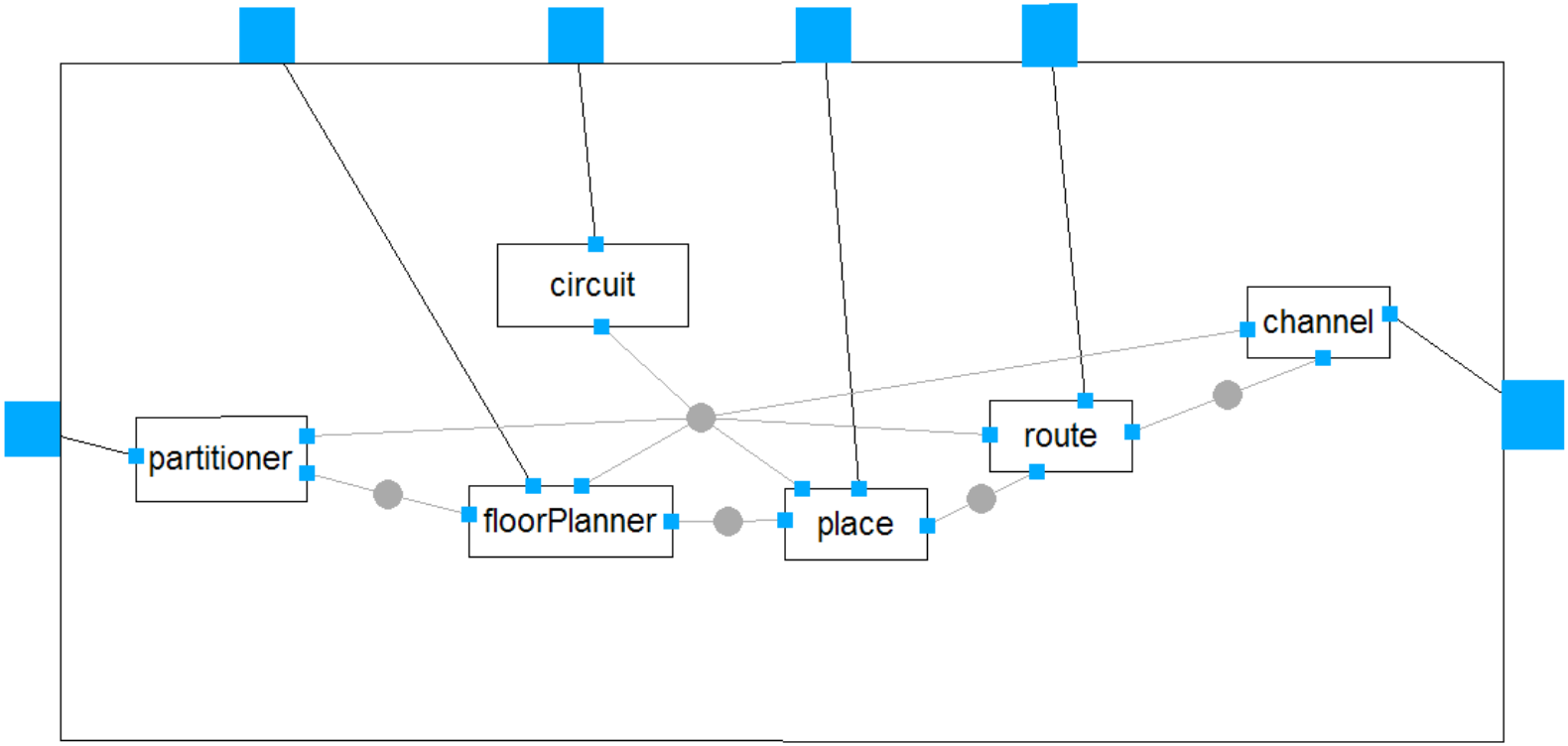
Aphyds System





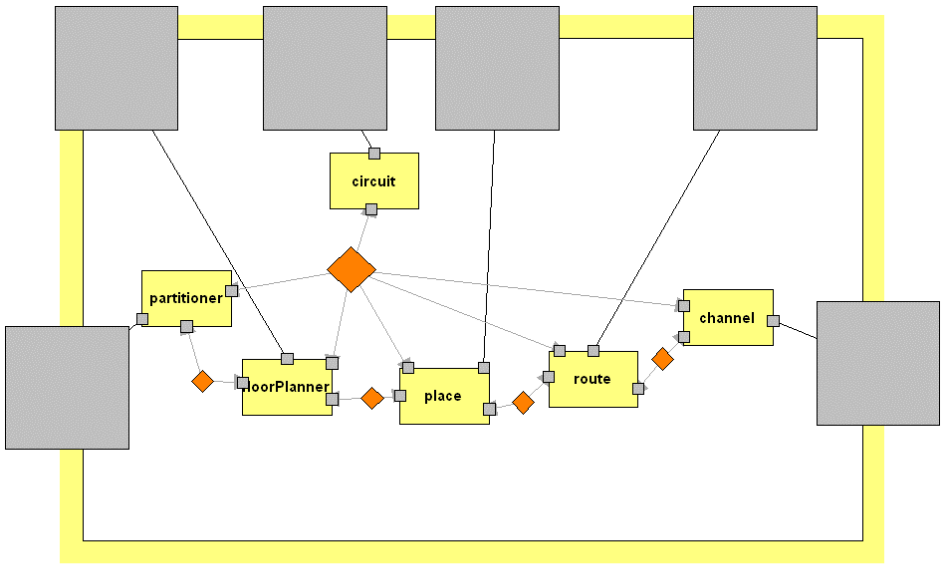


circuitModel details



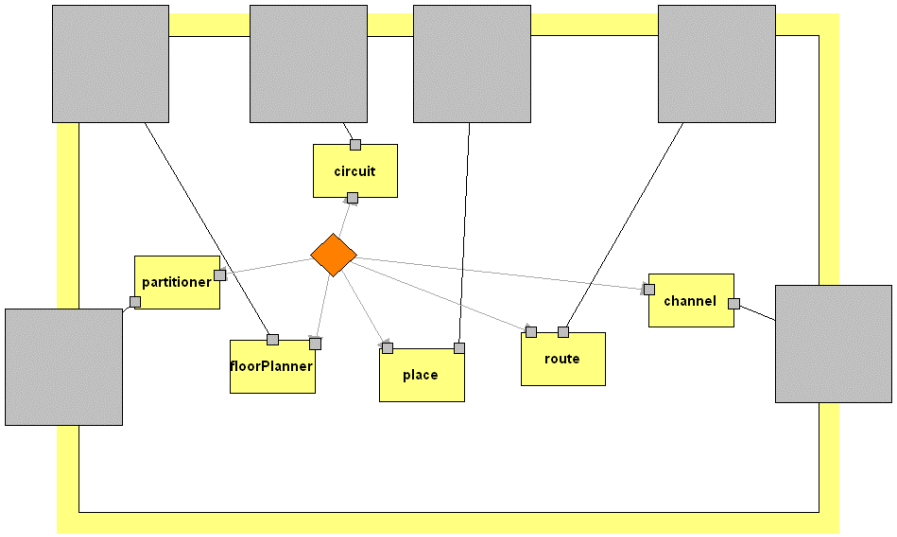
First Divergence: Extra Connectors!

The “data flow” connectors in the original Architect’s model do exist!



circuitModel
Representation - repmodel

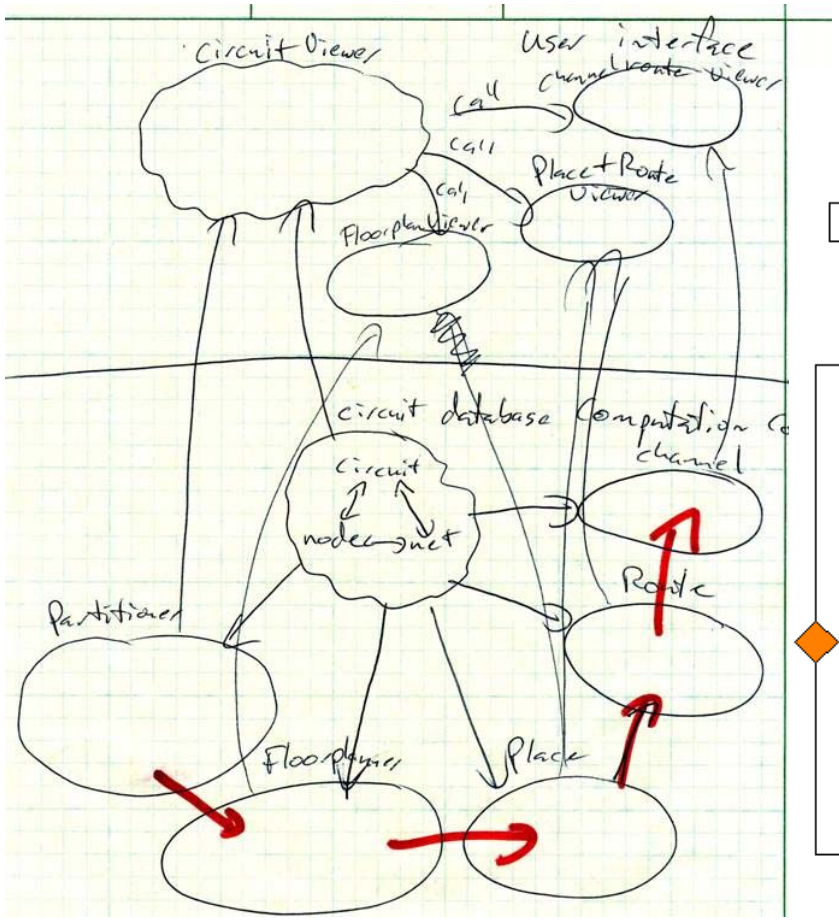
Before



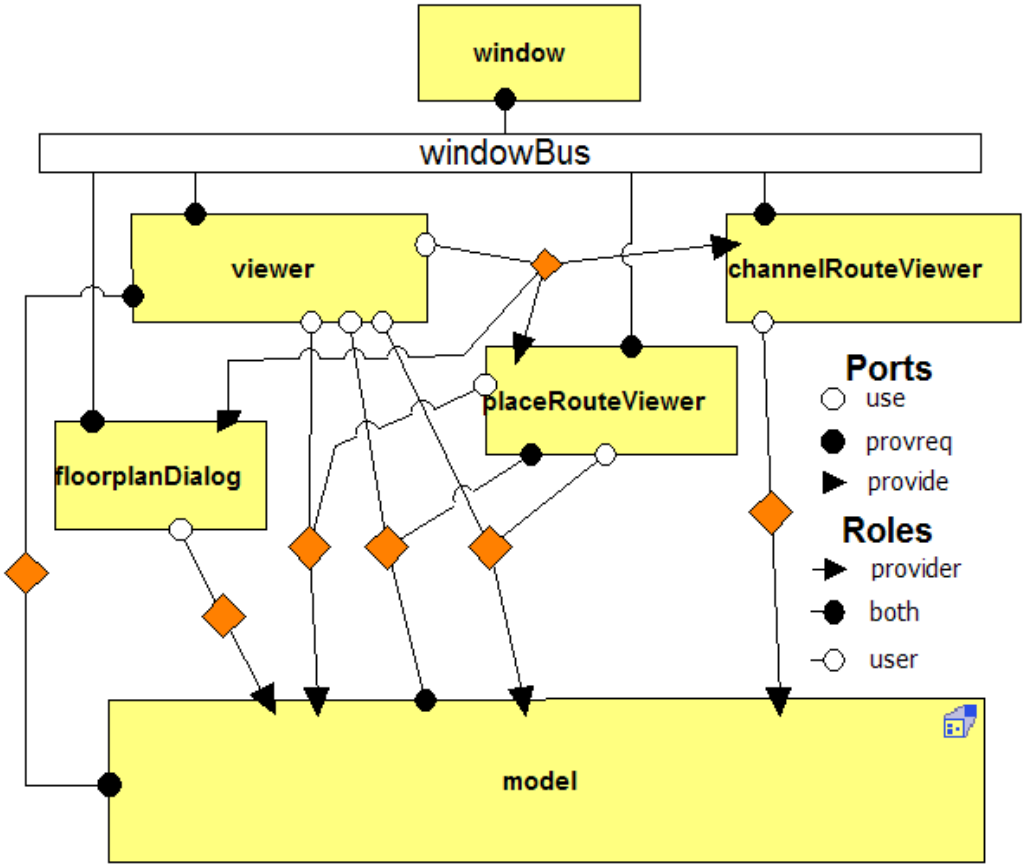
circuitModel
Representation - repmodel

After

Many Other Divergences



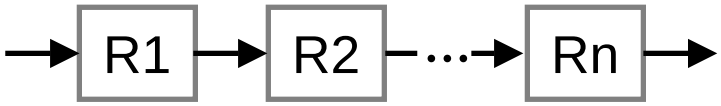
Before

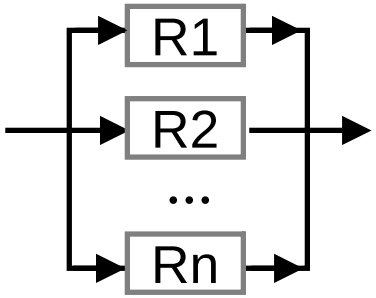


After

Reliability Block Diagrams

- Determine aggregate reliability from the parts, for certain styles





$$R_{sys} = \prod_{i=1}^{n} R_i$$

Serial Composition

$$R_{sys} = 1 - \prod_{i=1}^{n} (1 - R_i)$$

Parallel Composition

Source: Abd-Allah, Ahmed, “Extending Reliability Block Diagrams to Software Architectures”, USC Technical Report USC-CSE-97-501.

Conclusions

- Our approach encourages continuous use of architectural views and analyses throughout the software life cycle
- Work at appropriate level of abstraction
  - Architectural styles, properties, analyses, …
- Ensure that design is proper abstraction of implementation

Questions?

References

- Acme
  - http://www.cs.cmu.edu/~acme
- ArchJava
  - http://archjava.fluid.cs.cmu.edu/