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System Architecture Specification Based on Behavior Models

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Motivation

One of the major concerns in Systems Architecture design is the question of the behavior of the system.

We suggest an approach for building system behavior models based on the concepts of event and event traces.

This yields executable architecture models and the ability to reason about system's behavior.

Objectives

- To make architecture models executable on an abstract machine, so that it becomes possible early in the system development phase to perform testing and verification of the top level system design and to enable automatic assertion verification.
- To provide a method and tools for extracting multiple views from the architecture models (e.g. DODAF views).
- To provide the method for system stepwise refinement from the top level architecture models to the detailed design and implementation models, supported by tools for sanity checks and refinement consistency checks.
- To provide formalism for specifying system's environment models, so that the system architecture can be tested and verified in the interaction with its environment, supporting the system safety assessment by identifying the hazard states that may emerge from such interaction.

Monterey Phoenix

- An approach to formal software system architecture specification based on **behavior models**.

- The behavior of the system is defined as a set of events (**event trace**) with two basic relations: **precedence** and **inclusion**.

- The structure of event trace is specified using **event grammars** and other constraints organized into schemas.

- The **schema** framework is amenable to stepwise architecture refinement, reuse, composition, visualization, and application of automated tools for consistency checks.

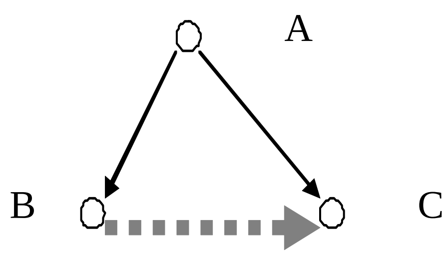
Basic Concepts

Event - any detectable action in system's or environment's behavior

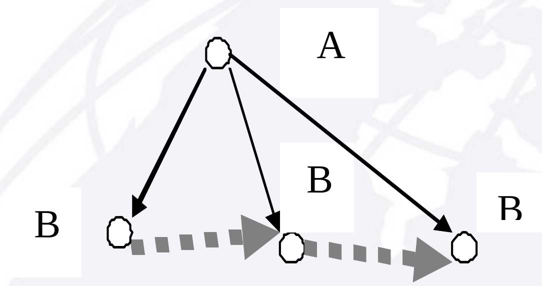
Event trace - set of events with two basic relations, **precedence** (PRECEDES) and **inclusion** (IN)

Event grammar

The rule A:: B C; specifies the event trace

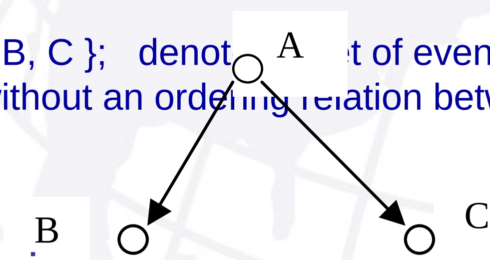


A:: (* B *); means an ordered sequence of zero or more events of the type B



A:: (B | C); denotes alternative

A:: { B, C }; denotes a set of events B and C without an ordering relation between them



- Graph grammar
- Both basic relations are partial orderings
- Event trace is always directed acyclic graph

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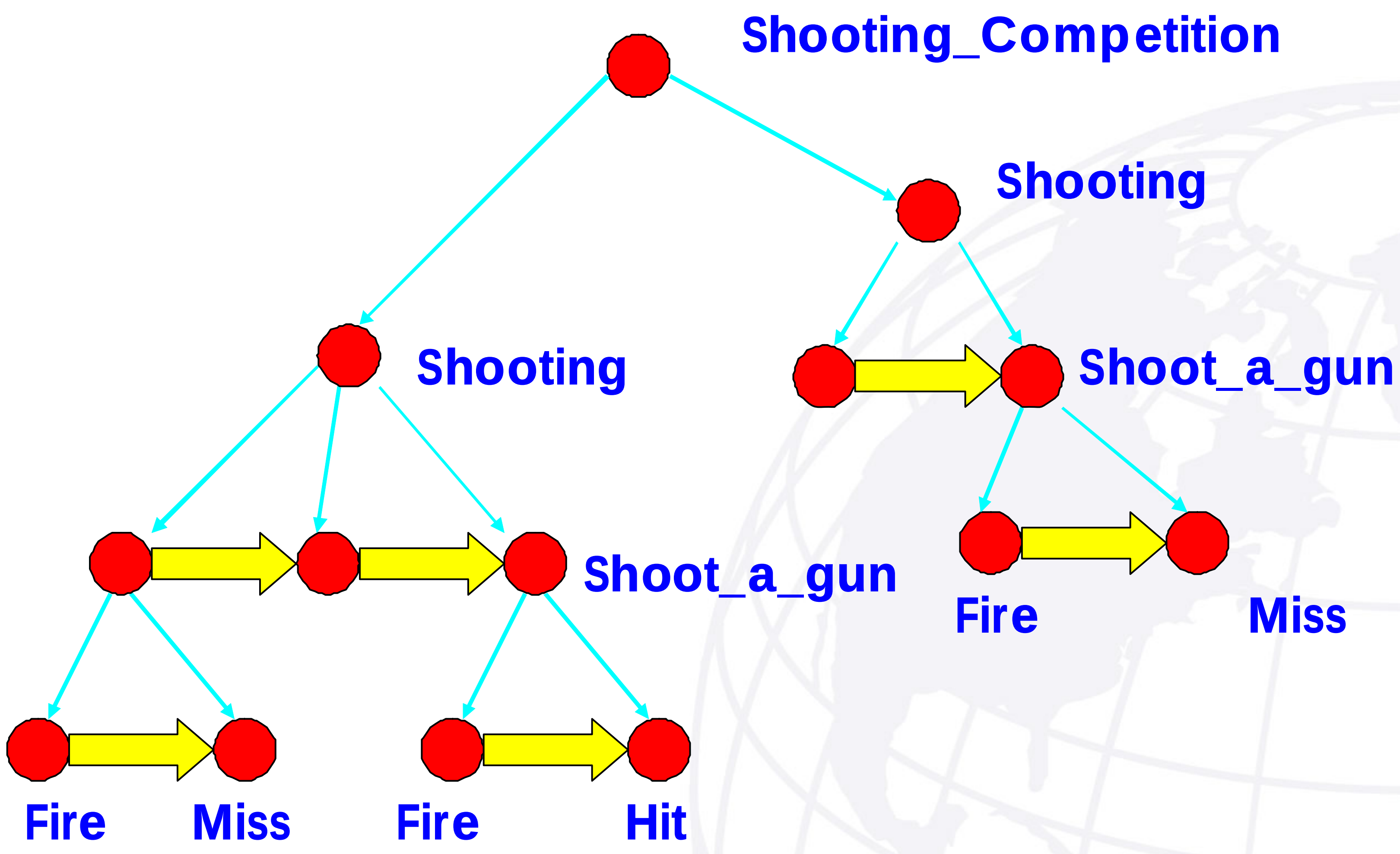
Example of an Event Grammar

Shooting_competition:: {* Shooting *};

Shooting:: (* Shoot *);

Shoot:: Fire (Hit | Miss);

Example of event trace



Schema

Simple_transaction

---

root TaskA:: Send;

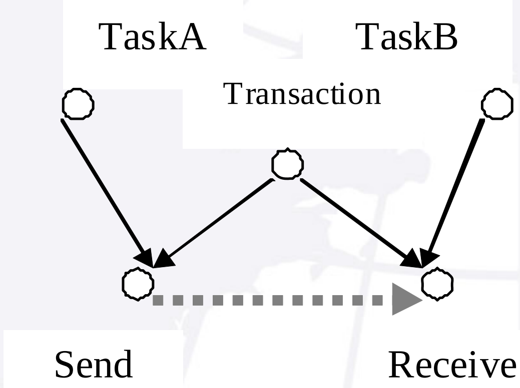
root TaskB:: Receive;

root Transaction:: Send Receive;

TaskA, Transaction **share all** Send;

TaskB, Transaction **share all** Receive;

The schema defines a set of event traces, i.e. the **behavior model**



Example of an event trace

If X, Y are root events, and Z is an event type

X, Y **share all** Z ≅ { v: Z | v IN X} = {w: Z | w IN Y}

Simple pipe/filter architecture

Multiple_synchronized_transactions

---

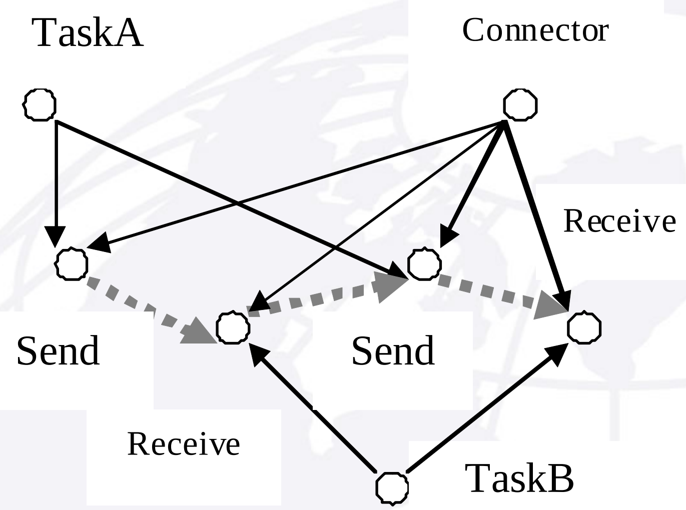
root TaskA:: (* Send *);

root TaskB:: (* Receive *);

root Connector:: (* Send Receive *);

TaskA, Connector **share all** Send;

TaskB, Connector **share all** Receive;



Example of an event trace

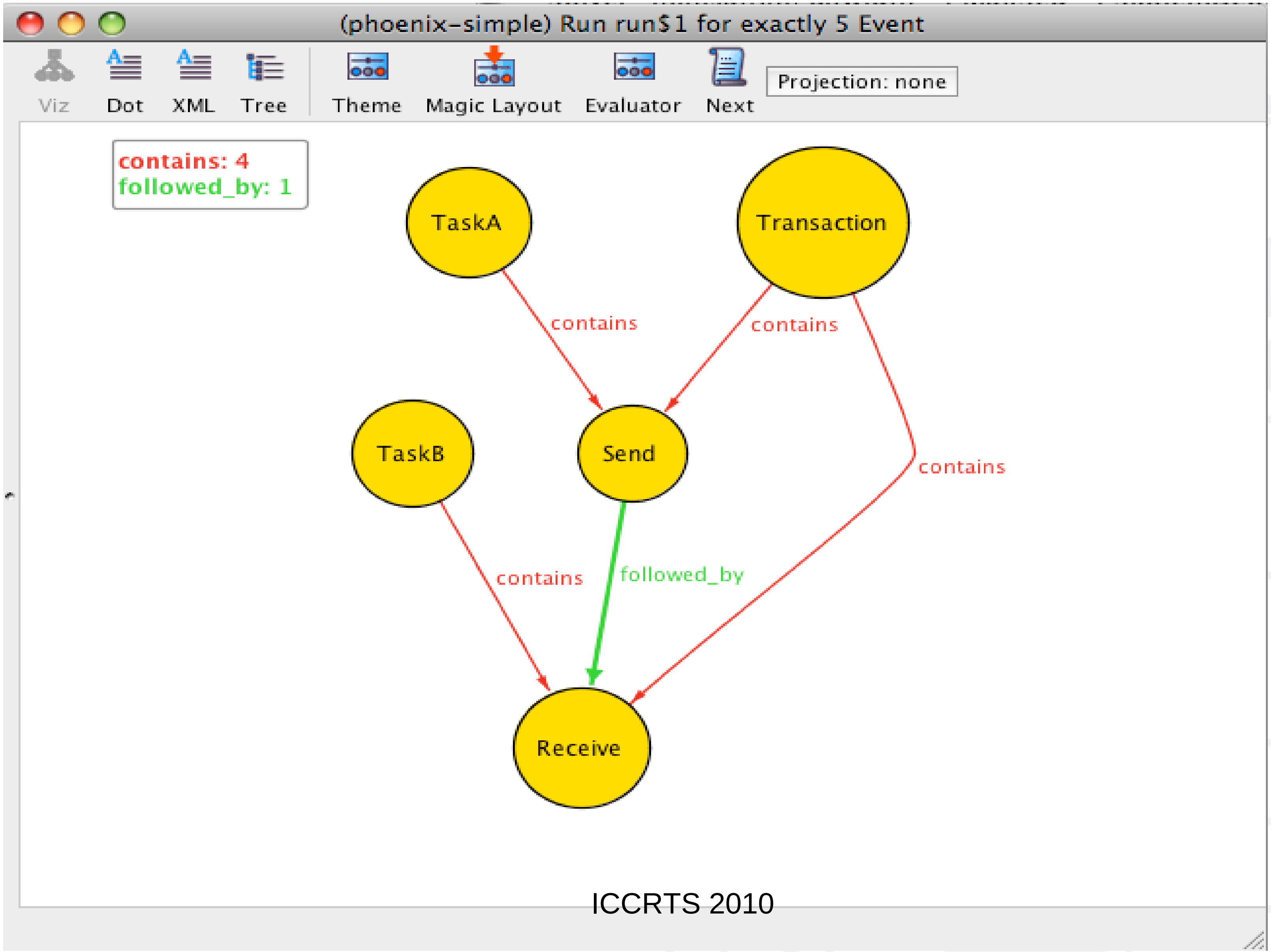
Semantics of the schema

Basic(S). This set contains only traces, which satisfy all schema's constraints, and have only events and relations imposed by the schema's grammar rules and Axioms.

The process of generating traces from Basic(S) defines the **semantics** of the schema S.

Schema is executable if there exists an Abstract Machine able to generate all traces from Basic(S). The schema represents instances of behavior (event traces), in the same sense as Java source code represents instances of program execution.

Alloy Analyzer is a good candidate for implementing the Phoenix Abstract Machine. This is a basic trace for Simple_transaction schema.

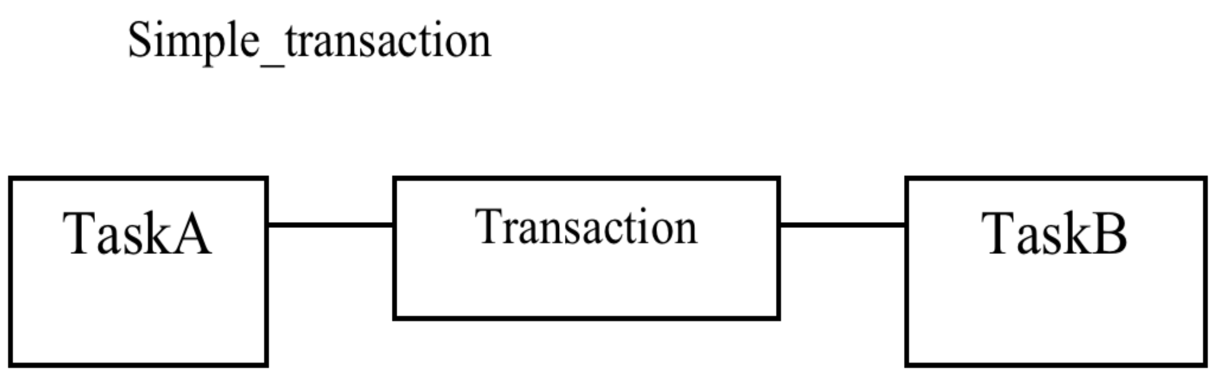


Extraction of Views

Predicate

CONNECTED(X, Y) = **exists** a ((a IN X) **and** (a IN Y))

may be used to extract simple diagrams from the schemas:



Example. Client/Server architecture

Client_server

```
root Client::      {* Request *};
root Server::      {* Provide *};
root Connector::  Initialize
                   {* ( Request Provide)  *}
                   Close;
```

Client, Connector **share all** Request;

Server, Connector **share all** Provide;

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Environment models

The User schema represents the environment behavior in which the Calculator operates.

```
User
__________________________________________
Use_calculator::   (* Perform_calculation *);

Perform_calculation::
                    Enter_number
                    Enter_operator
                    Enter_number
                    Request_result;

Enter_number:: (+ Press_digit_button +) ;
```

System behavior model

```
Calculator
Calculator_in_action::   (* Single_calculation *);

Single_calculation:: Get_number  Get_operator  Get_number
                     IF (Get_operator.operation == ‘+’) THEN
                                / Single_calculation.result =
                                  Get_number[1].value + Get_number[2].value; /
                     ELSE
                                / Single_calculation.result =
                                  Get_number[1].value – Get_number[2].value; /
                     Show_result;

Get_number::         / Get_number.value= 0; /
                     (* Get_digit
                        / Get_number.value =
                                Get_number.value * 10 +   Get_digit.value;/  *) ;

Show_result::        /show_result(ENCLOSING Single_calculation.result );/ ;
```

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Merged Behavior

he following schema defines the interaction between the User and the Calculator by tablishing a connection between events in the environment and in the system.

onnection

ess_digit_button:: /Get_digit.value = Press_digit_button.value;/
Get_digit ;

nter_operator:: / Get_operator.operation = Enter_operator.operation;/
Get_operator;

equest_result:: Show_result;

he model of a calculator interacting with the environment.

ser_and_Calculator

erge User, Calculator, Connection;

alculator, Connection **share all** Get_digit, Get_operator, Show_result;
ser, Connection **share all** Press_digit_button, Enter_operator, Request_result;

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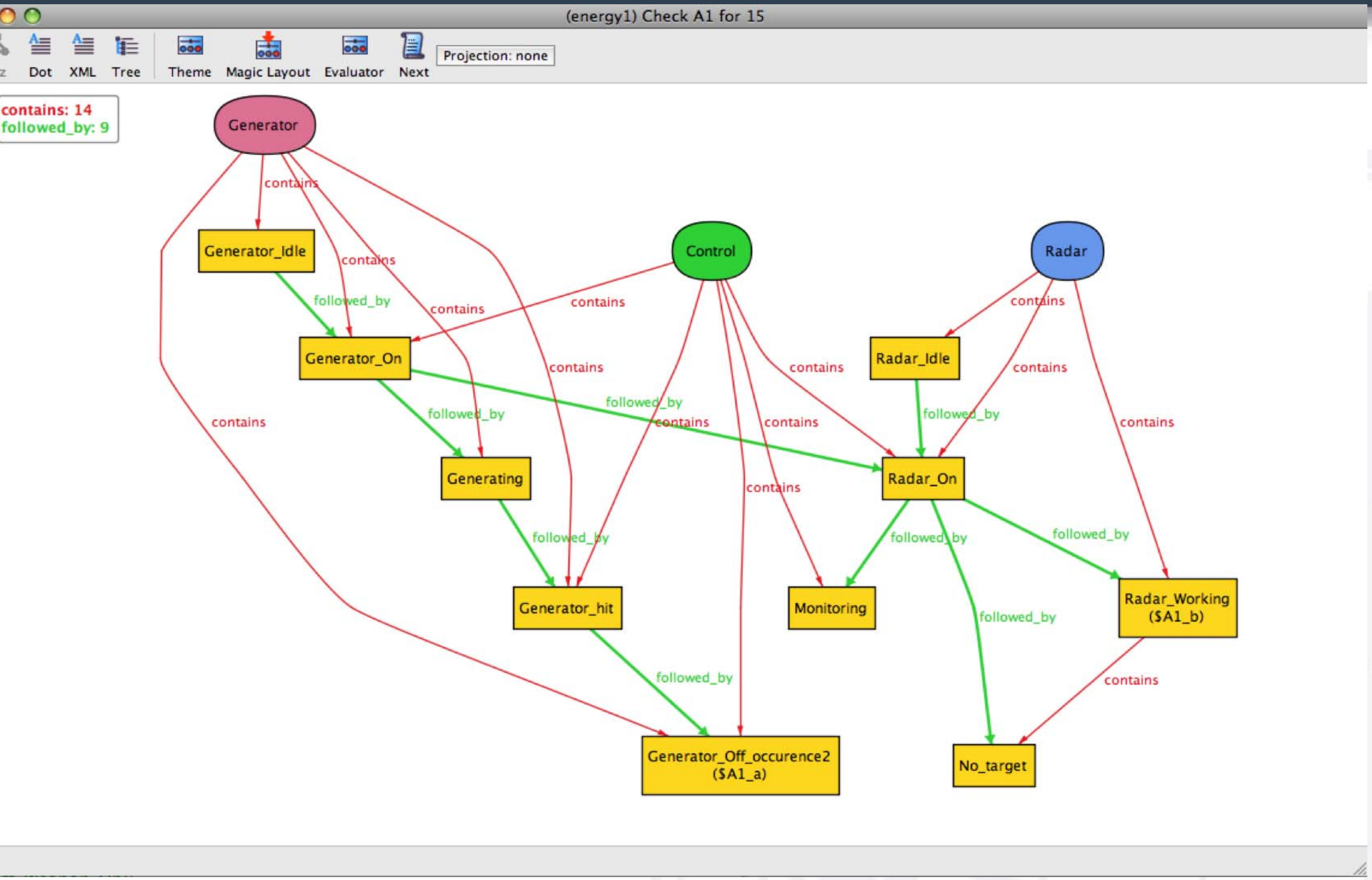
Assertion checking: Warfighting Example



A counterexample for assertion:

not exists Slice(Generator_off, Radar_Working);