Behavioral Models for Systems Architecture and Workflow Analysis

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"Every system has an architecture, whether or not it is documented and understood."

ROZANSKI, N., WOODS, E., 2012,
Software Systems Architecture, 2nd Edition, Addison-Wesley

Technical Rationale

- A system architecture description belongs to a high level of abstraction, ignoring many of the implementation details, such as algorithms and data structures
- The architecture plays a role as the bridge between requirements and implementation of a system
- Errors in early system design are the most expensive to fix when detected later in the development lifecycle
- Modeling is an approach to the design and verification of system architecture

Technical Rationale

- One of the major concerns in architecture design is the question of the behavior of the system
- An architecture specification should be supportive for the refinement process
- Composition operations focus on the interactions between the parts of the system
- An architecture of a system is considered in the context of the environment in which it operates, including business processes
- The architect needs a number of different views of the architecture for the various uses and users

What is Monterey Phoenix?

http://wiki.nps.edu/display/MP

MP is a framework for software system architecture and related workflow modeling with the focus on behavior of software system and its environment

Behavior is defined as a set of events (event trace) with two basic relations: precedence and inclusion

- The MP trace generator produces all possible scenarios of system behavior up to a scope limit.
- MP model separates component behaviors and component interactions.

The Innovations

- An **executable** system architecture model - Monterey Phoenix scenario generator can produce event traces with several hundred or small thousands of events

- An event trace **visualization framework** that enables human analysts to focus on the behavior of the system and provides **multiple views** for different stakeholders

- Mechanisms to run **queries** on the automatically generated event traces, and a language for event trace analysis (**assertion checking**)

The main MP innovations in BPM

- Traditional business process modeling frameworks (BPEL, BPMN, UML, IDEF) are constrained by the *"single flowchart"* paradigm

- MP separates component behaviors from the component interaction, and thus provides a multidimensional picture of concurrent behaviors, with overlapping threads of process phases and participating actors

Basic concepts for behavior modeling

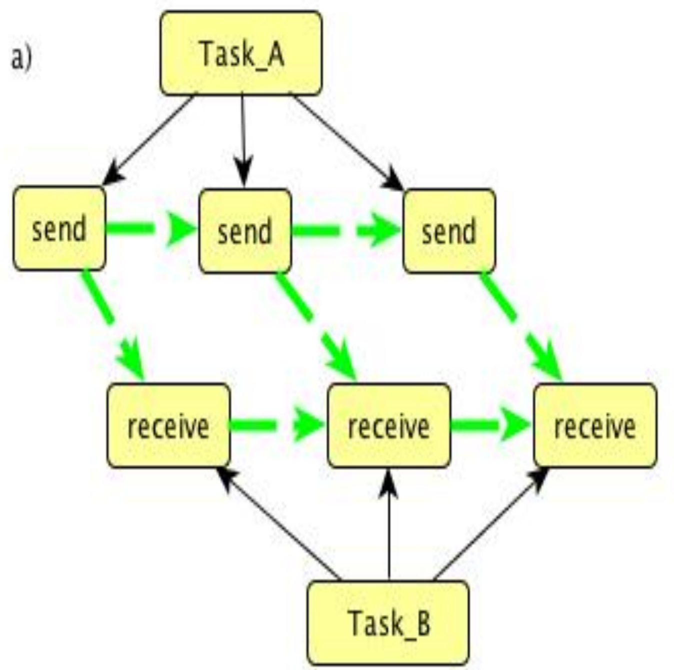
Event - any detectable action in system's or environment's behavior

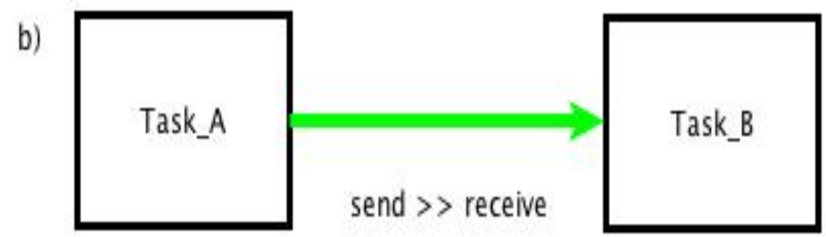
Event trace - set of events with two basic partial ordering relations, **precedence** (PRECEDES) and **inclusion** (IN)

Event grammar - specifies the structure of possible event traces

A simple pipe/filter architecture pattern

```
SCHEMA   simple_message_flow
ROOT Task_A:     (* send *);
ROOT Task_B:     (* receive *);
COORDINATE     $x: send       FROM Task_A,
               $y: receive  FROM Task_B
               DO        ADD $x  PRECEDES  $y;  OD;
```





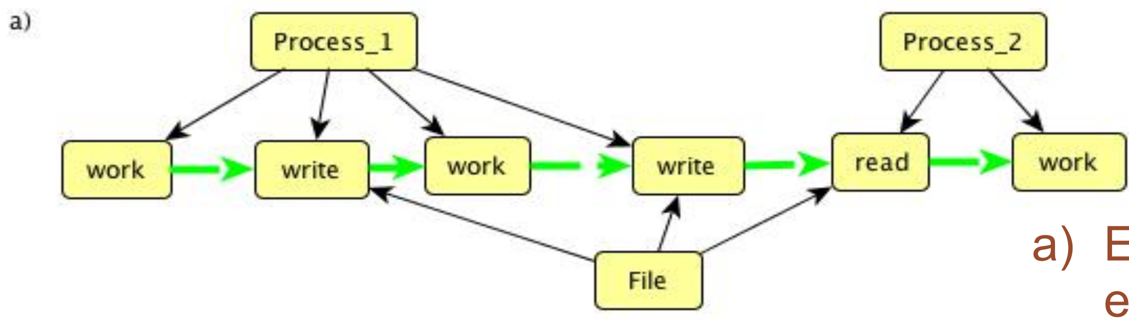
a) Example of a composed event trace

b) An architecture view for the schema

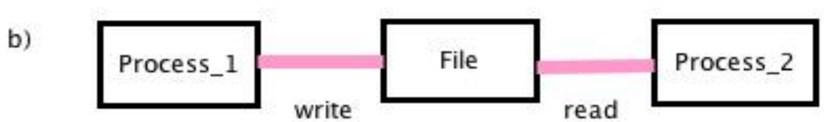
Data items as behaviors

Data items are represented by actions that may be performed on that data

```
SCHEMA          Data_flow
ROOT Process_1:       (*  work   write  *);
ROOT Process_2:       (* ( read | work ) *);
ROOT File:            (+ write +)  (* read *);
Process_1, File       SHARE ALL   write;
Process_2, File       SHARE ALL   read;
```



a) Example of a composed event trace



b) An architecture view

Architecture Verification & Validation

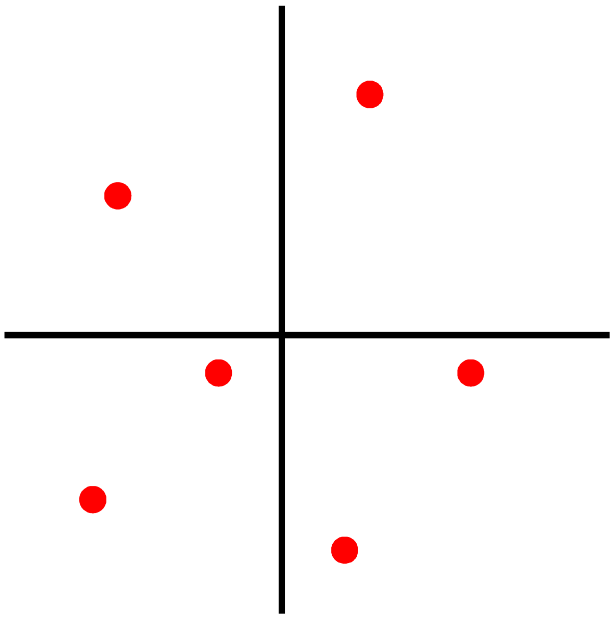
Advantages of Monterey Phoenix approach compared with the common simulation tools are as follows:

- Means to write **assertions** about the system behavior and tools to verify those assertions.
- **Exhaustive search** through all possible scenarios (up to the scope limit).
  - The **Small Scope Hypothesis**: most flaws in models could be demonstrated on small counterexamples
- Integration of the architecture models with **environment models** for verifying system's behavior on typical scenarios (Use Cases).
- **Event attributes**, like timing, can be used for non-functional requirements (like performance estimates) V/V and queries (like critical path estimates in PERT diagrams).
- Assigning **probabilities** to certain events makes it possible to obtain statistical estimates for system behaviors.

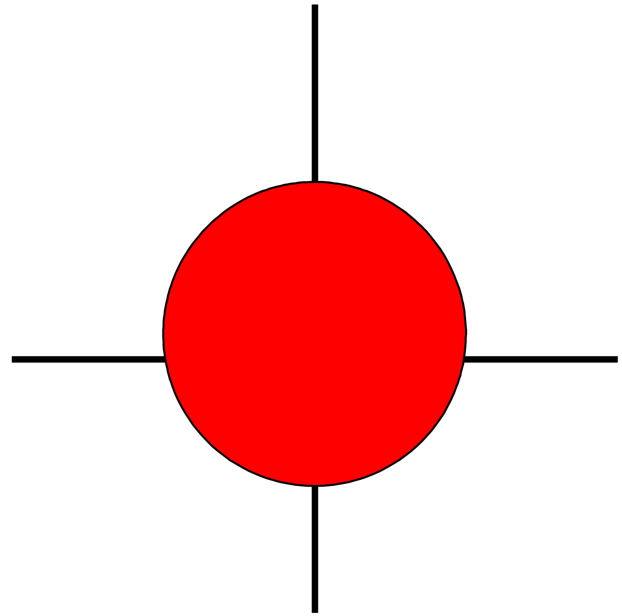
Architecture verification & validation

- It is much easier for different stakeholders to understand and verify stand-alone scenarios (Use Cases) neither the complete formal description of the system
- Scenario inspection in MP can be automated by assertion checking tools
- Interactions of subsystems and environment can be used for detecting emerging behaviors of System of Systems
- Different views can be automatically extracted and visualized for different stakeholder needs

Model verification within limited scope



Testing:
A few cases of arbitrary size



Scope-complete:
All cases within a small bound

Implementation

On-line MP editor/trace generator and a set of pre-loaded examples are available at

http://firebird.nps.edu

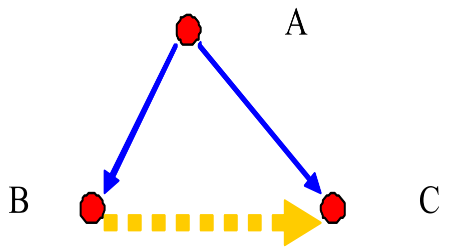
MP wiki with Crash Course and reading materials (publicly available part):
https://wiki.nps.edu/display/MP/Monterey+Phoenix+Home

MP model checking tool was implemented at the National University of Singapore by Dr. Jin Song Dong's team

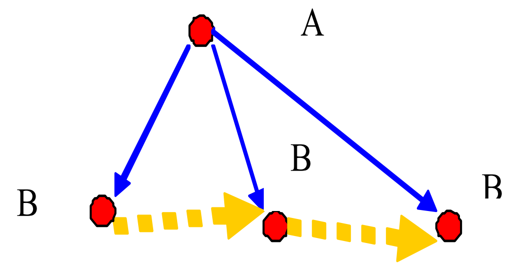
Backup slides

Event grammar

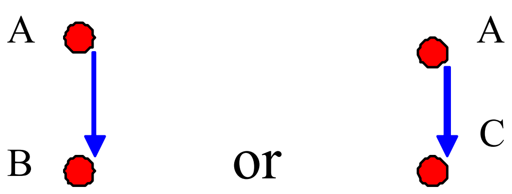
The rule A:: B C; specifies the event trace



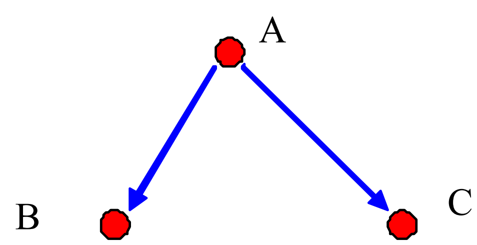
A:: (* B *); means an ordered sequence of zero or more events of the type B.



A:: (B | C); denotes alternative



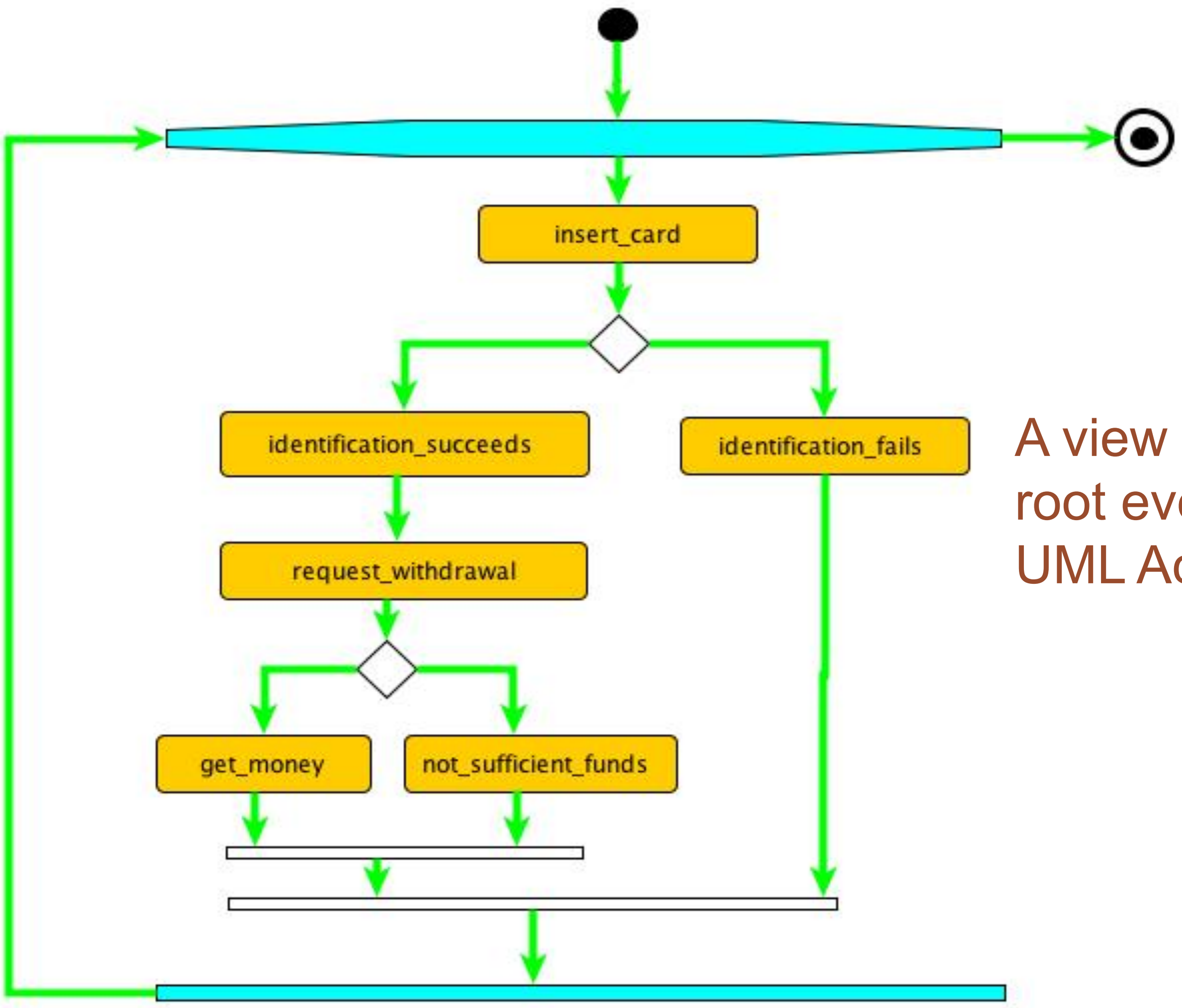
A:: { B, C }; denotes a set of events B and C without an ordering relation between them



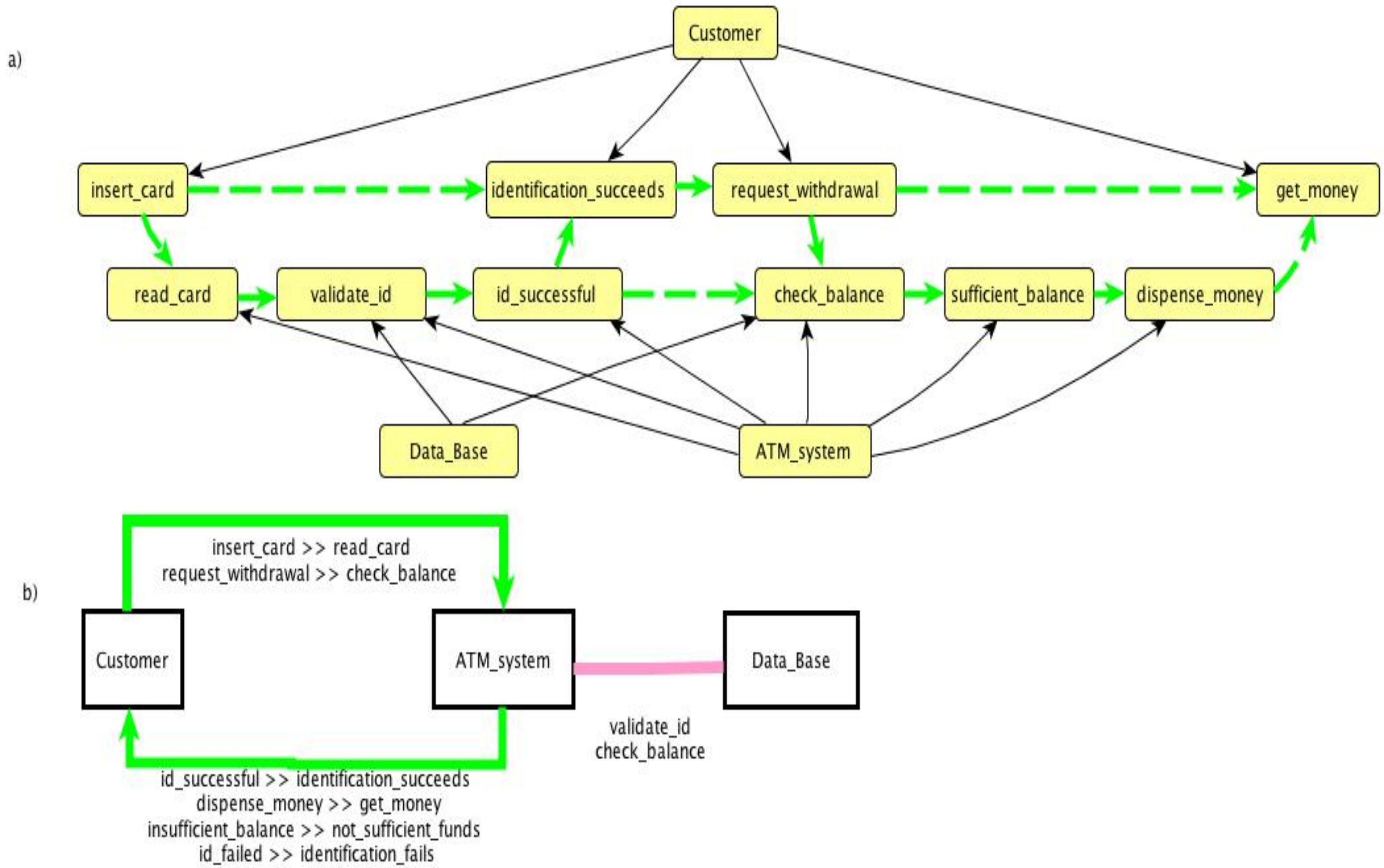
Integrating environment's behavior

```
SCHEMA            ATM_withdrawal
ROOT Customer:    (*  insert_card
                  ( (  identification_succeeds  request_withdrawal  ( get_money | not_sufficient_funds ) )  |
                       identification_fails   )     *);
ROOT ATM_system:  (*  read_card   validate_id
                         ( id_successful          check_balance
                                 (  (sufficient_balance    dispense_money) |
                                    unsufficient_balance )                     |
                           id_failed    )   *);
ROOT Data_Base:   (* ( validate_id | check_balance ) *);

Data_Base,  ATM_system SHARE ALL validate_id, check_balance ;

COORDINATE        $x: insert_card           FROM Customer,
                  $y: read_card             FROM ATM_system     DO ADD $x PRECEDES $y; OD;
COORDINATE        $x: request_withdrawal  FROM Customer,
                  $y: check_balance         FROM ATM_system  DO ADD $x PRECEDES $y; OD;
COORDINATE        $x: identification_succeeds FROM Customer,
                  $y: id_successful            FROM ATM_system   DO ADD $y PRECEDES $x; OD;
COORDINATE        $x: get_money             FROM Customer,
                  $y: dispense_money        FROM ATM_system    DO ADD $y PRECEDES $x; OD;
COORDINATE        $x: not_sufficient_funds FROM Customer,
                  $y: unsufficient_balance FROM ATM_system   DO ADD $y PRECEDES $x; OD;
COORDINATE        $x: identification_fails    FROM Customer,
                  $y: id_failed                FROM ATM_system      DO ADD $y PRECEDES $x;OD;
```

Architecture view on the component behavior



A view on the Customer root event behavior as UML Activity Diagram



a) An example of event trace (Use Case) for the ATM_withdrawal schema
b) An architecture view for the ATM_withdrawal schema