Facing Uncertainty in Web Service Compositions

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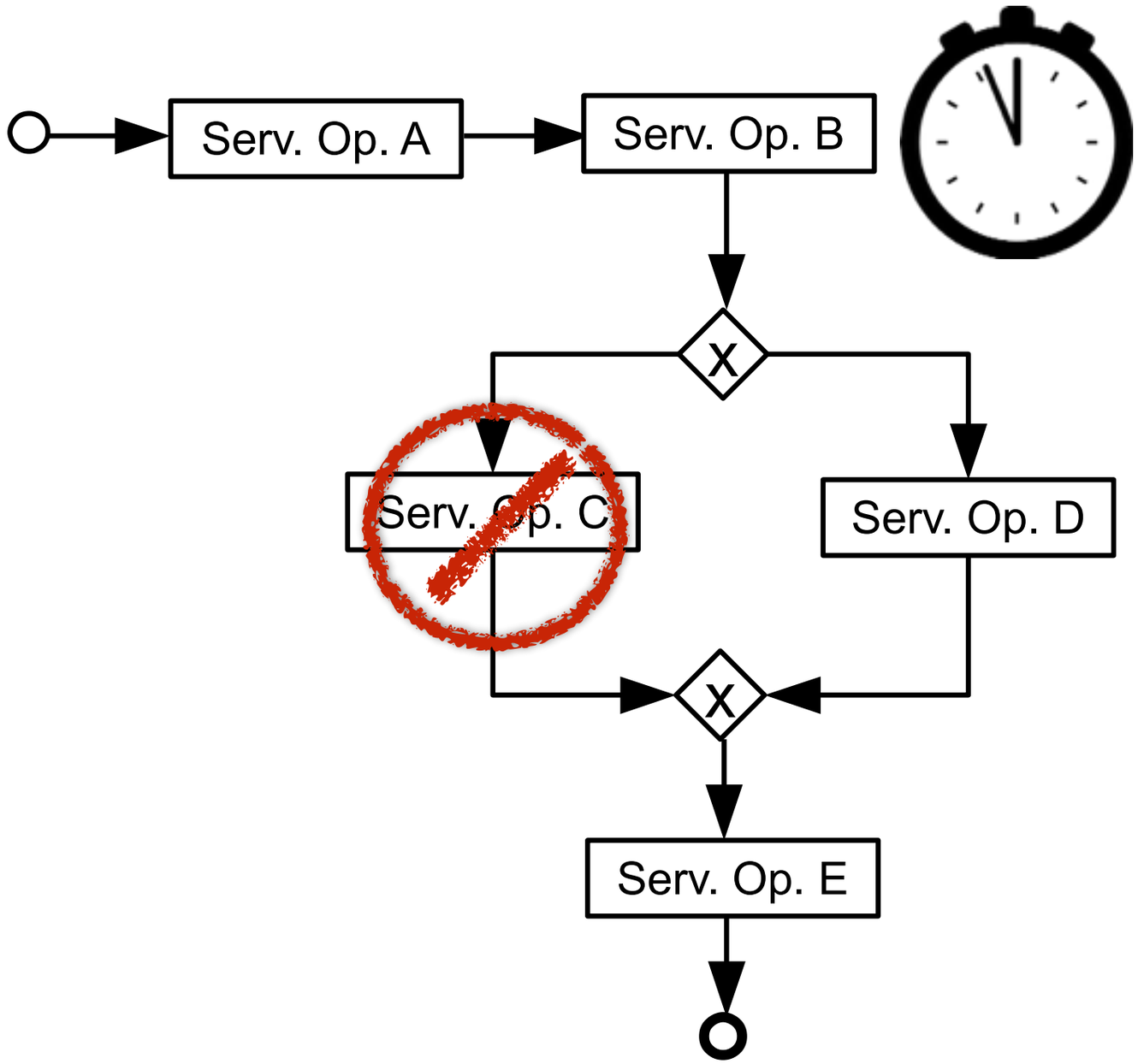
Software also runs in complex & heterogeneous computing infrastructures.

Translate the ideas of adaptation in the natural world to software.

Adaptability is emerging as a **necessary capability** of **highly-dynamic systems** (Hong et al., 2009).

Systems based on **Web service compositions**



Dynamic adaptations: the service composition **self-adjusts at runtime** to do the following:

- Keep the **quality** of the service composition
- Offer **extra functionality** depending on the context
- **Protect** the system
- Make the system **more usable**

Related work on **dynamic adaptation** of service compositions has traditionally tended to focus on:

1. Variability constructs at the language level

2. Brokers

1. Variability constructs at the language level

It can **hinder reasoning** about adaptations with **complex** and **error-prone scripts** (Fleurey and Solberg, 2009)

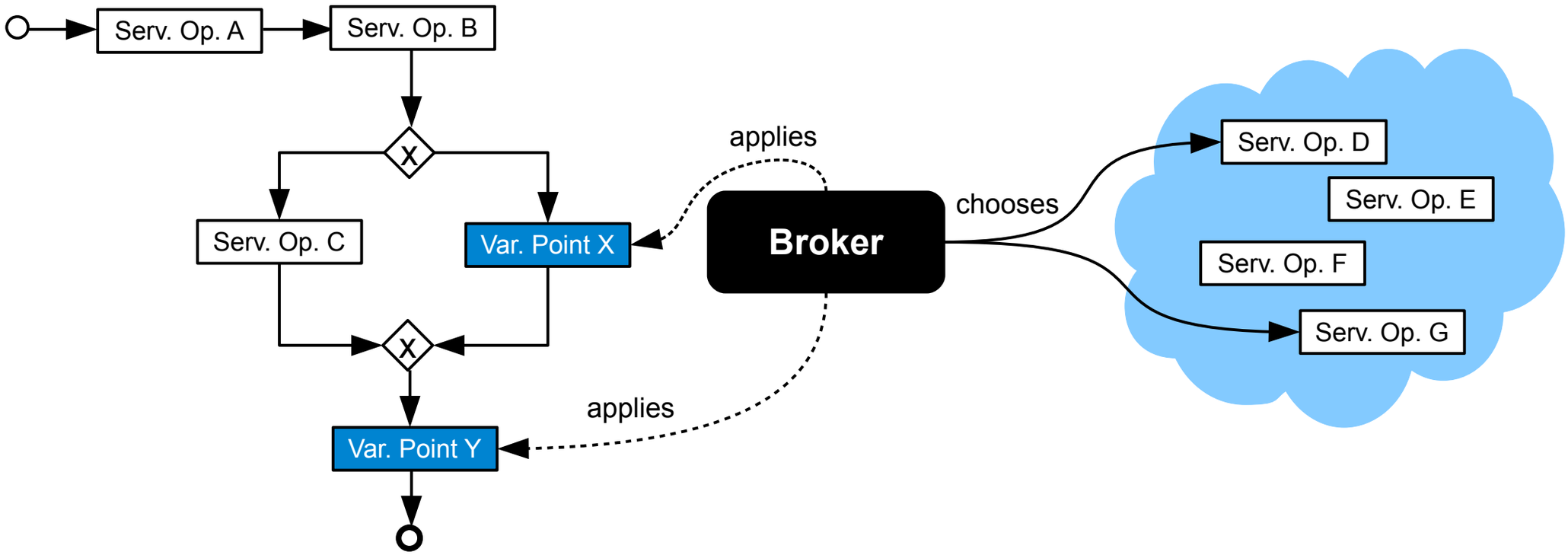
```
<vxbpel:VariationPoint name="VPService1">
  <vxbpel:Variants>
    <vxbpel:Variant name="Service1A">
      <vxbpel:VPBpelCode>
        <invoke ... partnerLink="service1a"/>
      </vxbpel:VPBpelCode>
    </vxbpel:Variant>
    <vxbpel:Variant name="Service1B">
      <vxbpel:VPBpelCode>
        <invoke ... partnerLink="service1b"/>
      </vxbpel:VPBpelCode>
    </vxbpel:Variant>
  </vxbpel:Variants>
</vxbpel:VariationPoint>
```

Koning et al., 2009

Need to manage adjustments at a **higher level of abstraction**.

2. Brokers

Most research works **lack support** for analyzing the inherent **variability** of dynamic adaptation at **design time**



Need to manage **variability** at **design time** and at **runtime**.

Tendency: dynamic adaptation of service compositions in the **closed-world**. However, **the world is increasingly open!**

Closed World	Open World
Stable contexts (the context changes *slowly*)	**Dynamic contexts** (focused on *ubiquitous* computing infrastructures. The context changes *rapidly*)
Anticipated changes (*foreseen* context events)	**Unanticipated changes** (*unknown* context events)

Need to manage dynamic adjustments in the unpredictable **open world**.

Contributions

Need to manage adjustments at a **higher level of abstraction**.

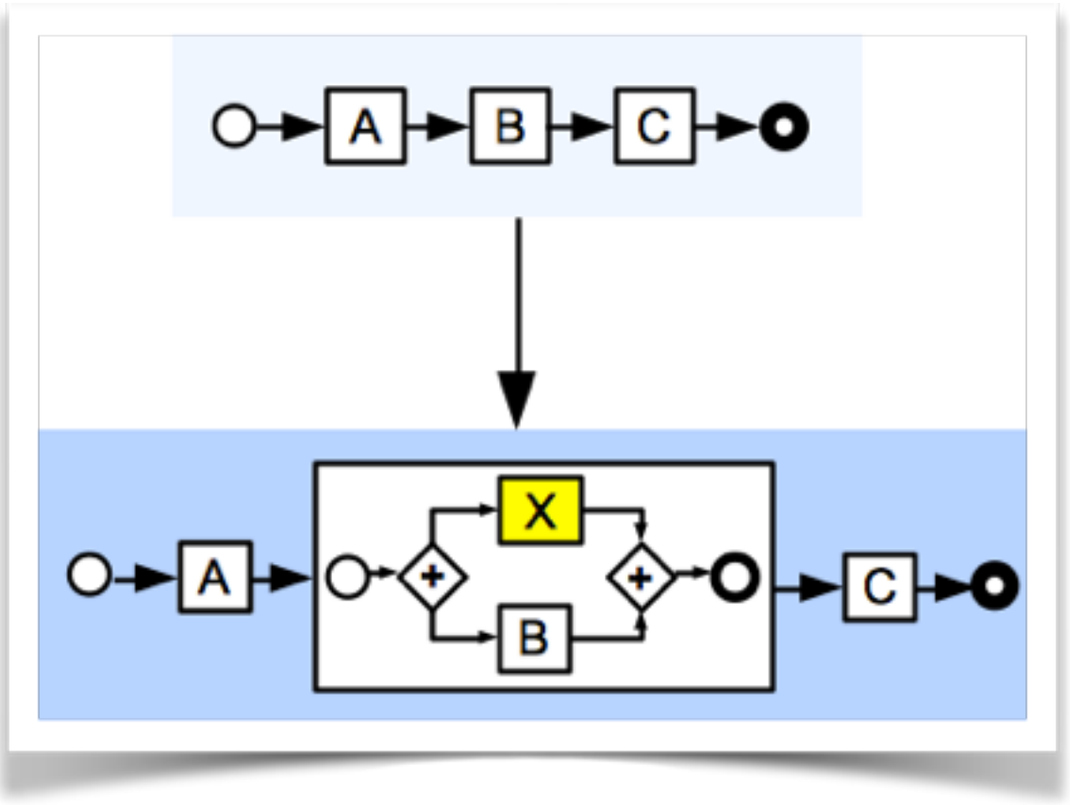
Need to manage dynamic adjustments in the unpredictable **open world**.

An approach to manage **some situations** of **uncertainty in the open world** by **dynamically evolving service compositions** through **models at runtime**.

Contributions

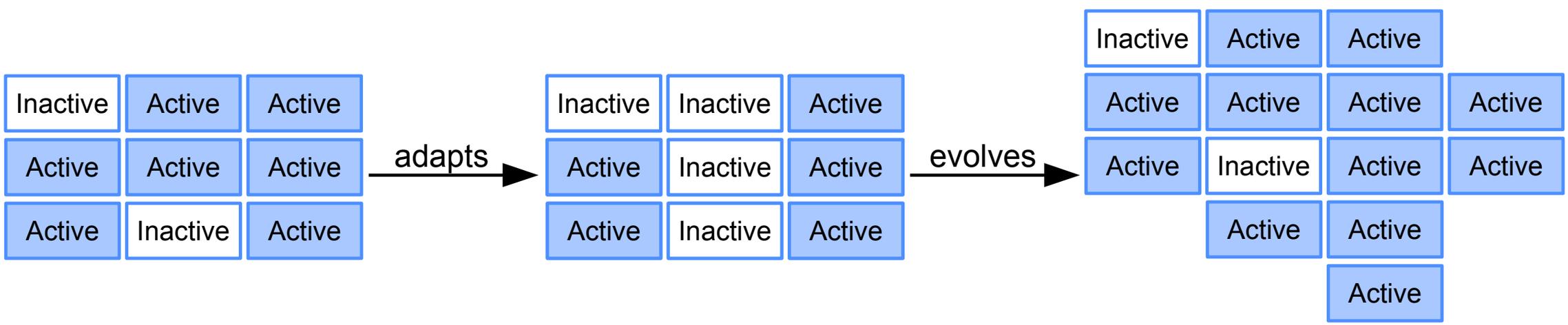
An approach to manage **some situations** of **uncertainty in the open world** by **dynamically evolving service compositions** through **models at runtime**.

Dynamic evolution: "The process of moving the service composition to a new version (which cannot be supported by predefined dynamic adaptations) in order to manage **unknown context events at runtime**." (Alférez and Pelechano, **MODELS** 2012)



Contributions

An approach to manage **some situations** of **uncertainty in the open world** by **dynamically evolving service compositions** through **models at runtime**.



Dynamic adaptations are carried out to make **punctual Dynamic evolutions** imply a **gradual structural or changes** in the service composition with **"known"** adaptation **architectural growth into a better state** in order to face policies. Dynamic adaptations **face particular "known" events in uncertainty** in the open world (Alférez and Pelechano, **MODELS the closed world** (Alférez and Pelechano, **SPLC** 2011; Alférez et 2012; Alférez and Pelechano, **ICWS** 2013) al., **JSS Elsevier** 2014).

Contributions

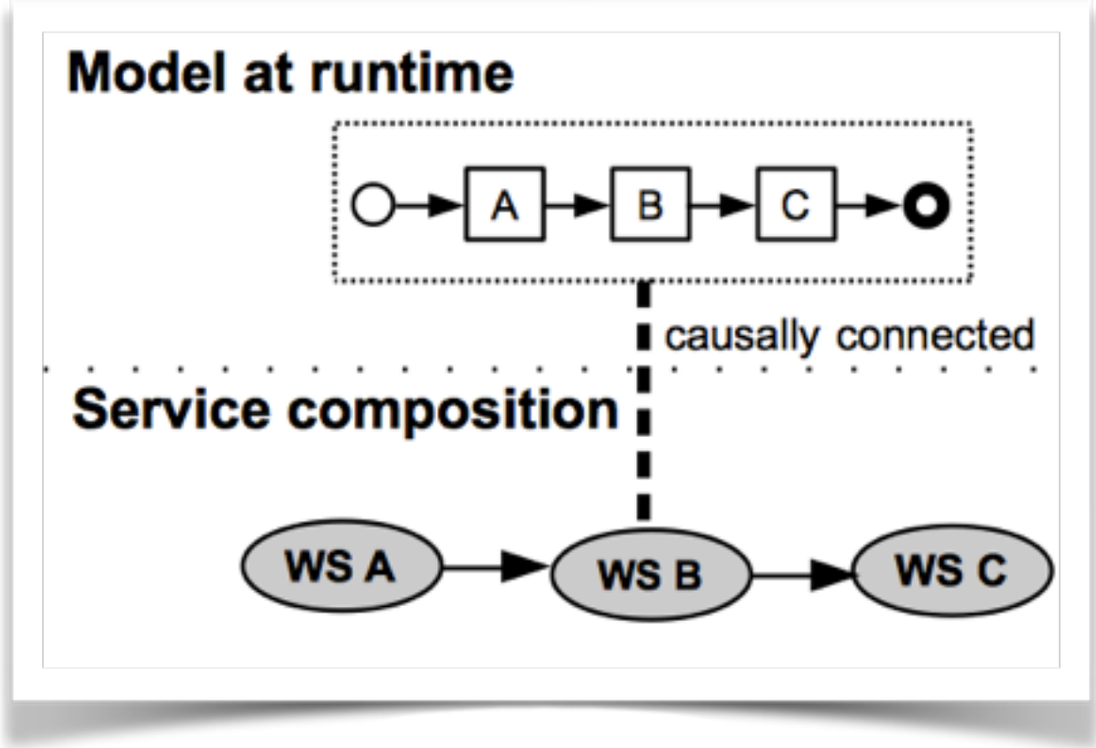
An approach to manage **some situations** of **uncertainty in the open world** by **dynamically evolving service compositions** through **models at runtime**.

In the open world, **uncertainty** is caused by how the service composition should deal with **unknown context events**.

Contributions

An approach to manage **some situations** of **uncertainty in the open world** by **dynamically evolving service compositions** through **models at runtime**.

Models at runtime: "Causally connected self-representations of the associated system that emphasize the structure, behavior, or goals of the system from a problem space perspective" (Blair, 2009).



Contributions

Need to manage **variability** at **design time** and at **runtime**.

A **tool-supported software engineering approach** for the **development** of context-aware service compositions from **design time** to **execution**.

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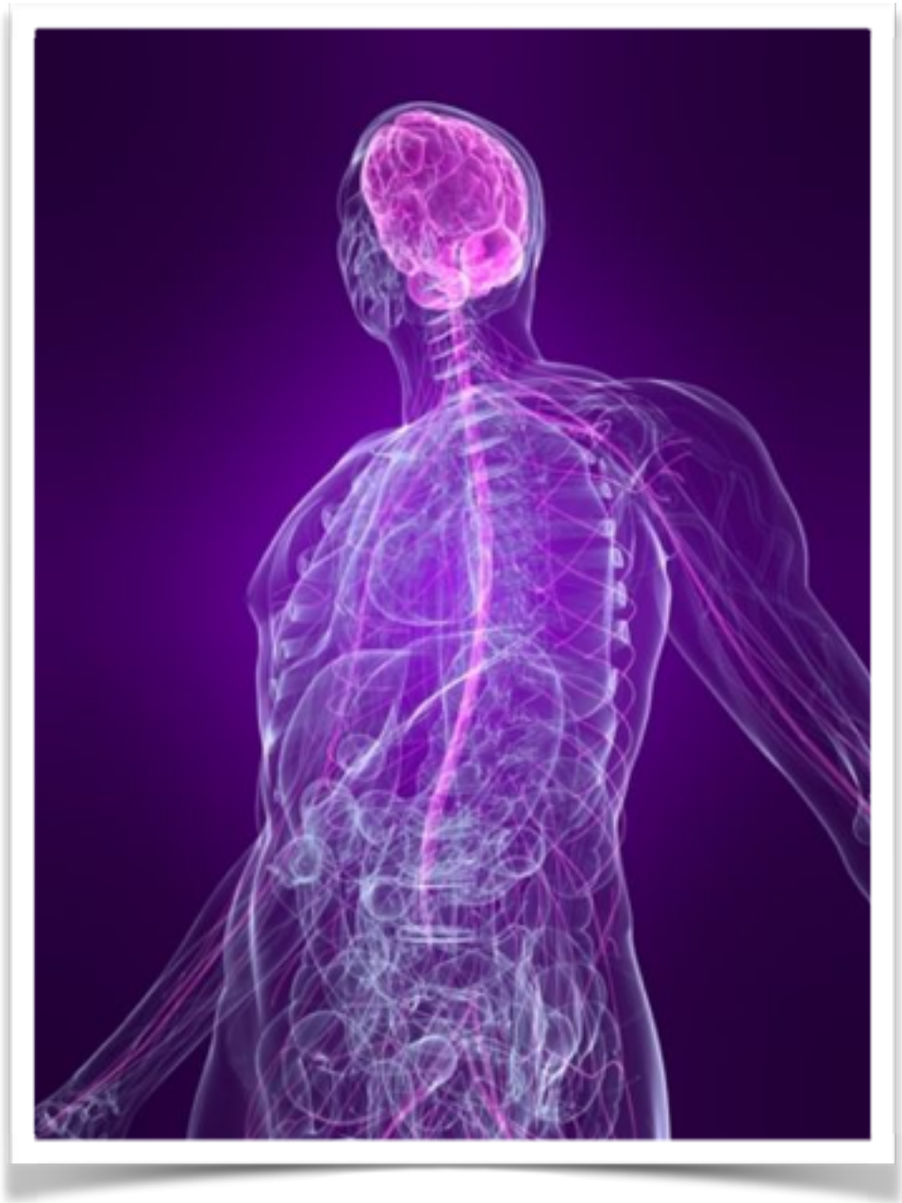
Design Time: Model-Driven Engineering

Runtime: Autonomic Computing

- AC is an initiative proposed by IBM.
- **Goal:** to develop computer systems with **self-management** capabilities.



Contributions

Solution

Modeling to Face Uncertainty in the Open World

Solution - Modeling to Face Uncertainty in the Open World

How to **preserve** expected **requirements** when the service composition faces **unknown context events** in the **open world**?

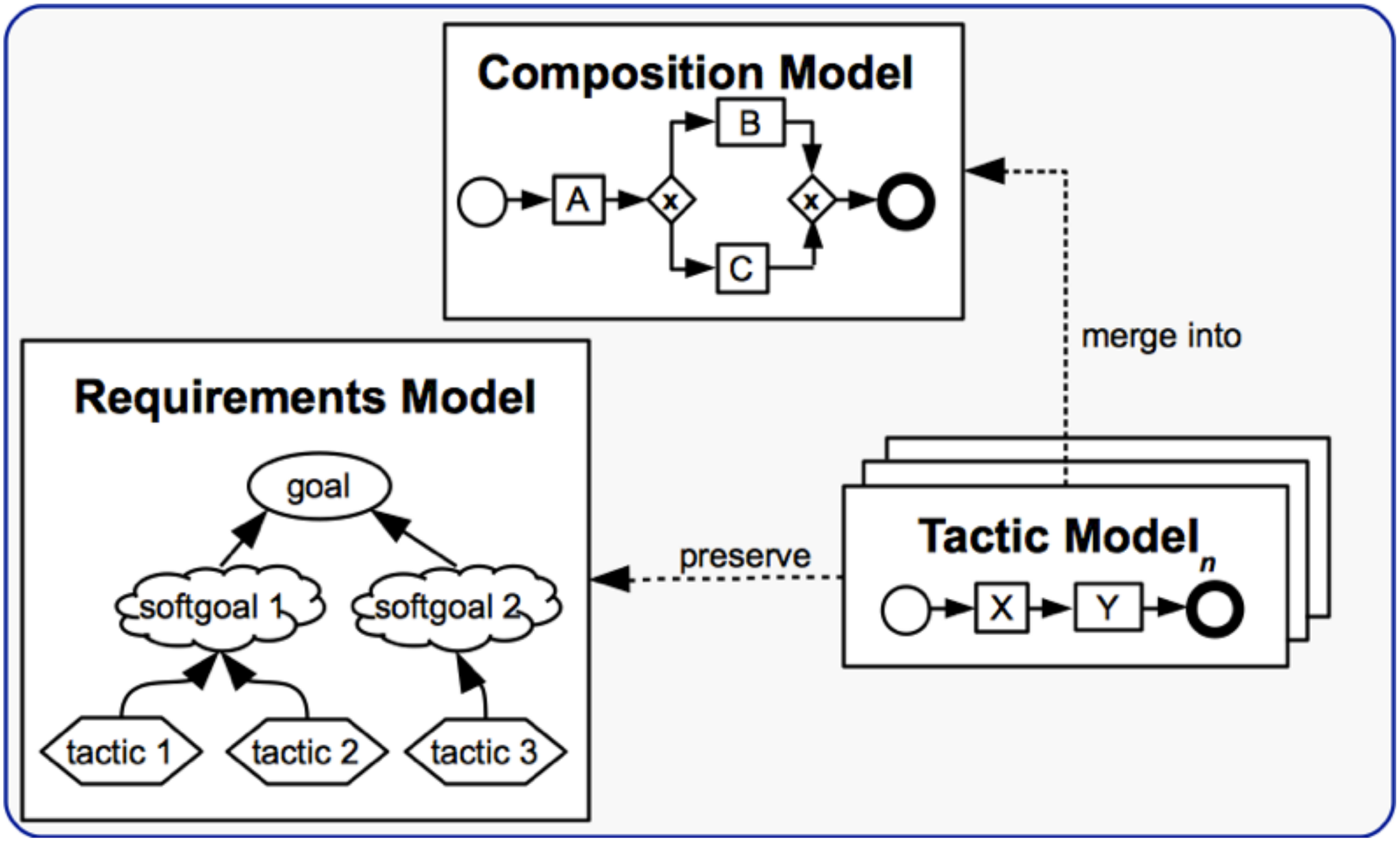
Tactics are **abstract last-resort surviving actions** to **preserve** the **requirements** that can be **negatively impacted** by **unknown context events** (Alférez and Pelechano, **MODELS** 2012).

Tactics try to **reduce** the impact of unknown context events in the open world.

Known Unknowns

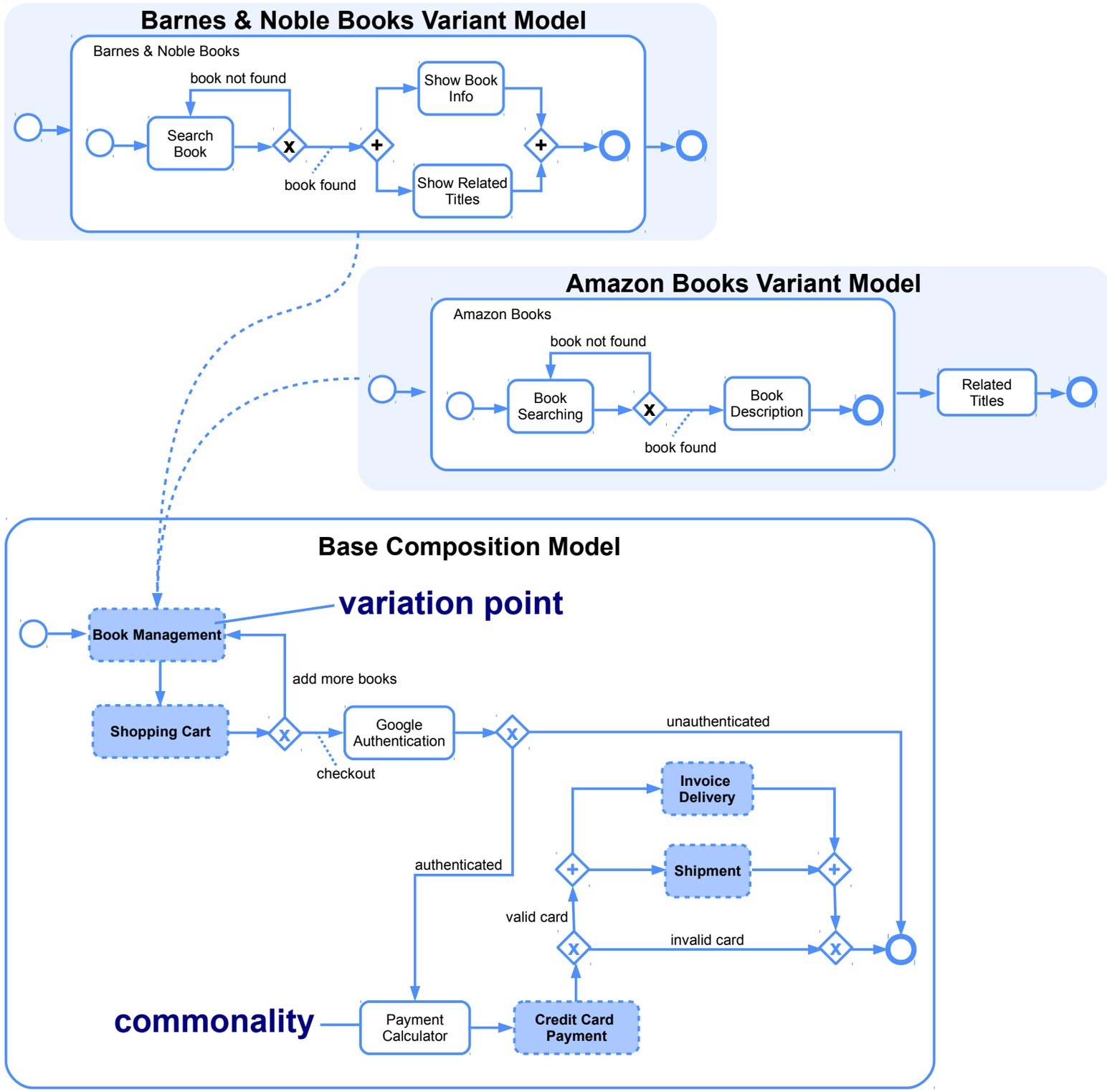
- **Goal:** To Win.
- **Unknown or unforeseen events:** Surprise assaults.
- **What to do?** Choose among a set of tactics to reach the goal - to scape vs. to do a frontal attack.
  - **Tactics** are **known beforehand**, but soldiers **do not know** to which specific arising **unknown context events** they will be applied.

Pieces of knowledge during execution to achieve dynamic evolution of service compositions.



Solution - Modeling to Face Uncertainty in the Open World

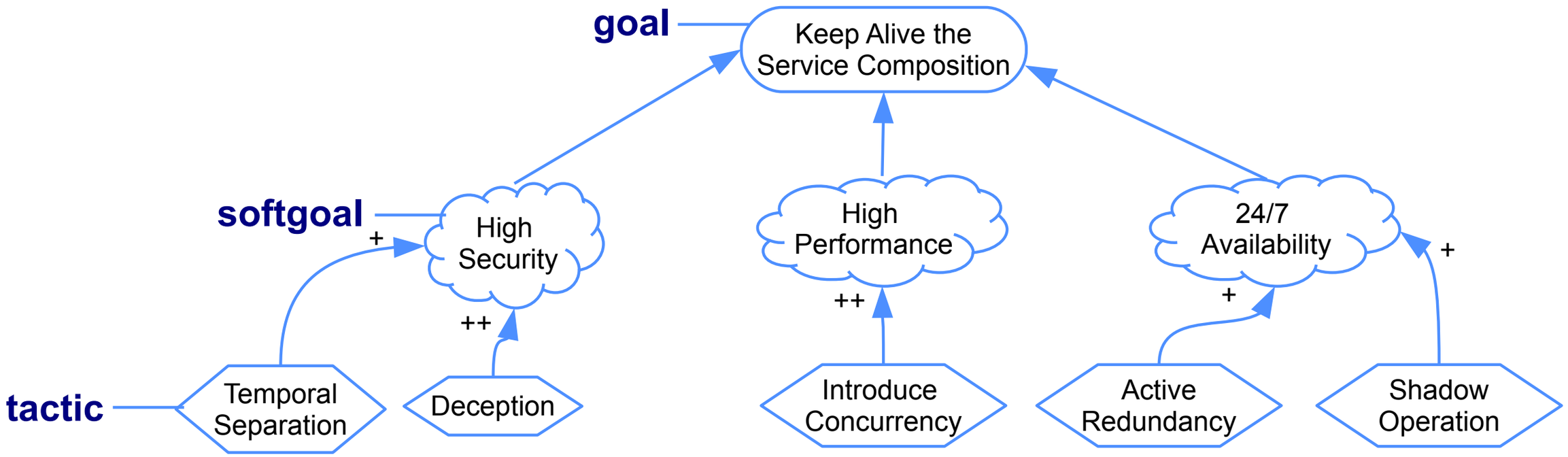
Composition Model



Extended Business Process Model and Notation (BPMN)

Solution - Modeling to Face Uncertainty in the Open World

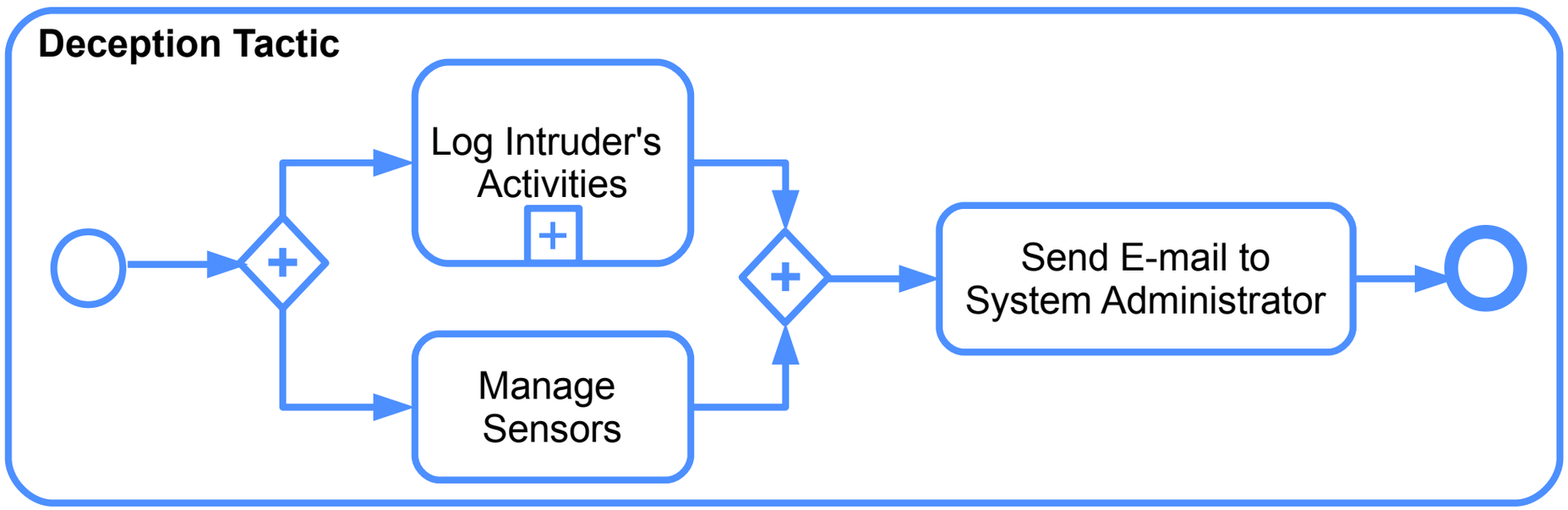
Requirements Model



Goal Model (Liu and Yu, 2004; Yu, 2009)

Solution - Modeling to Face Uncertainty in the Open World

Tactic Models



Tactic models express the tactical functionality to be triggered on the service composition to preserve requirements.

- They are **causally connected** to Web services that implement the tactical functionality.
- They are **merged** into the composition model at runtime.

How to find the **requirements** that can be affected by **unknown context events?**

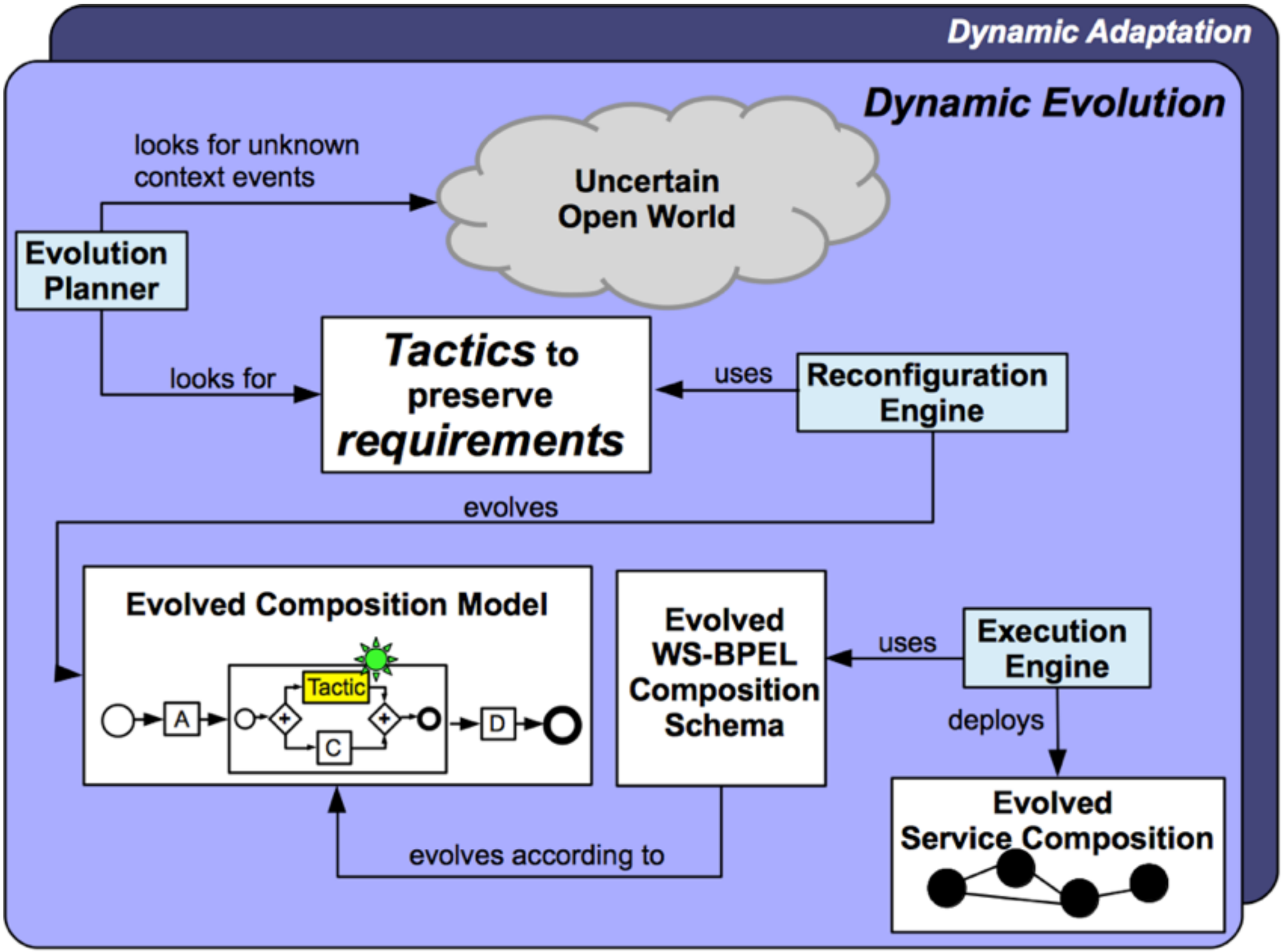
Knowledge base implemented as a rules file.

```
@prefix j.0: http://my.ontology#
[underAttack: (?s rdf:type j.0:WebService)
     (?s j.0:executionTime ?c)
     greaterThan(?c,5000)
     ->
     (?s rdf:type j.0:UnderAttack)
]

[affectedHighSecurityRequirement: (?s rdf:type j.0:UnderAttack)
     ->
     (?s rdf:type j.0:AffectedHighSecurityRequirement)
]
```

Achieving Dynamic Evolution through Models at Runtime

Solution - Achieving Dynamic Evolution through Models at Runtime

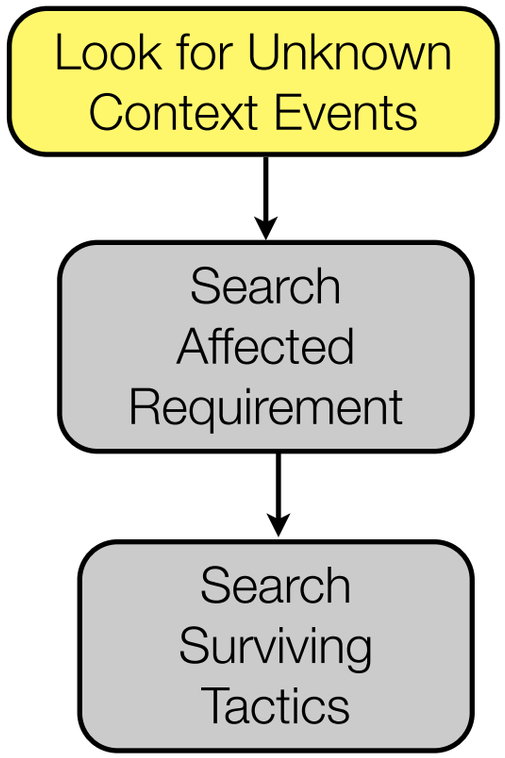


Solution - Achieving Dynamic Evolution through Models at Runtime

Evolution Planner

1) **Look for Unknown Context Events from the Collected Information:**

Periodically checks an updated **ontology** (Alférez and Pelechano, **SPLC** 2011; Alférez et al., **JSS Elsevier** 2014).

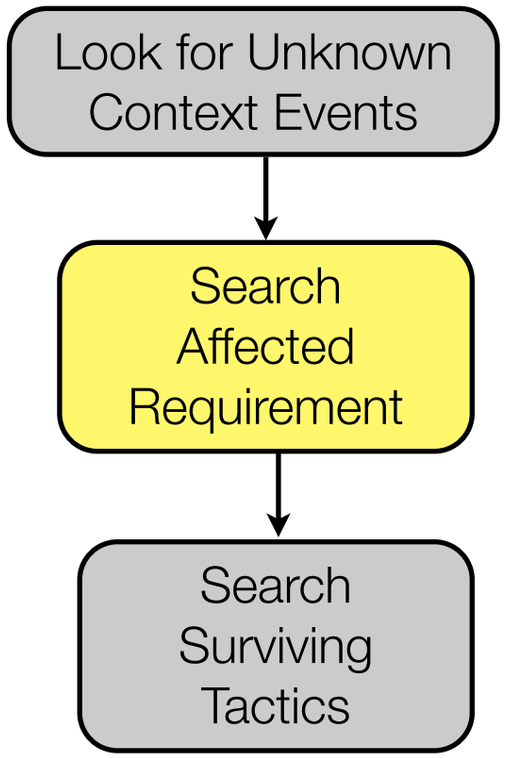


- An observed context event is considered as **unknown** when there are not predefined **context conditions** to deal with it. E.g. *UPSShipping, HasResponseTime, > 2,000 ms.*

Evolution Planner

2) **Search Affected Requirement(s)**:

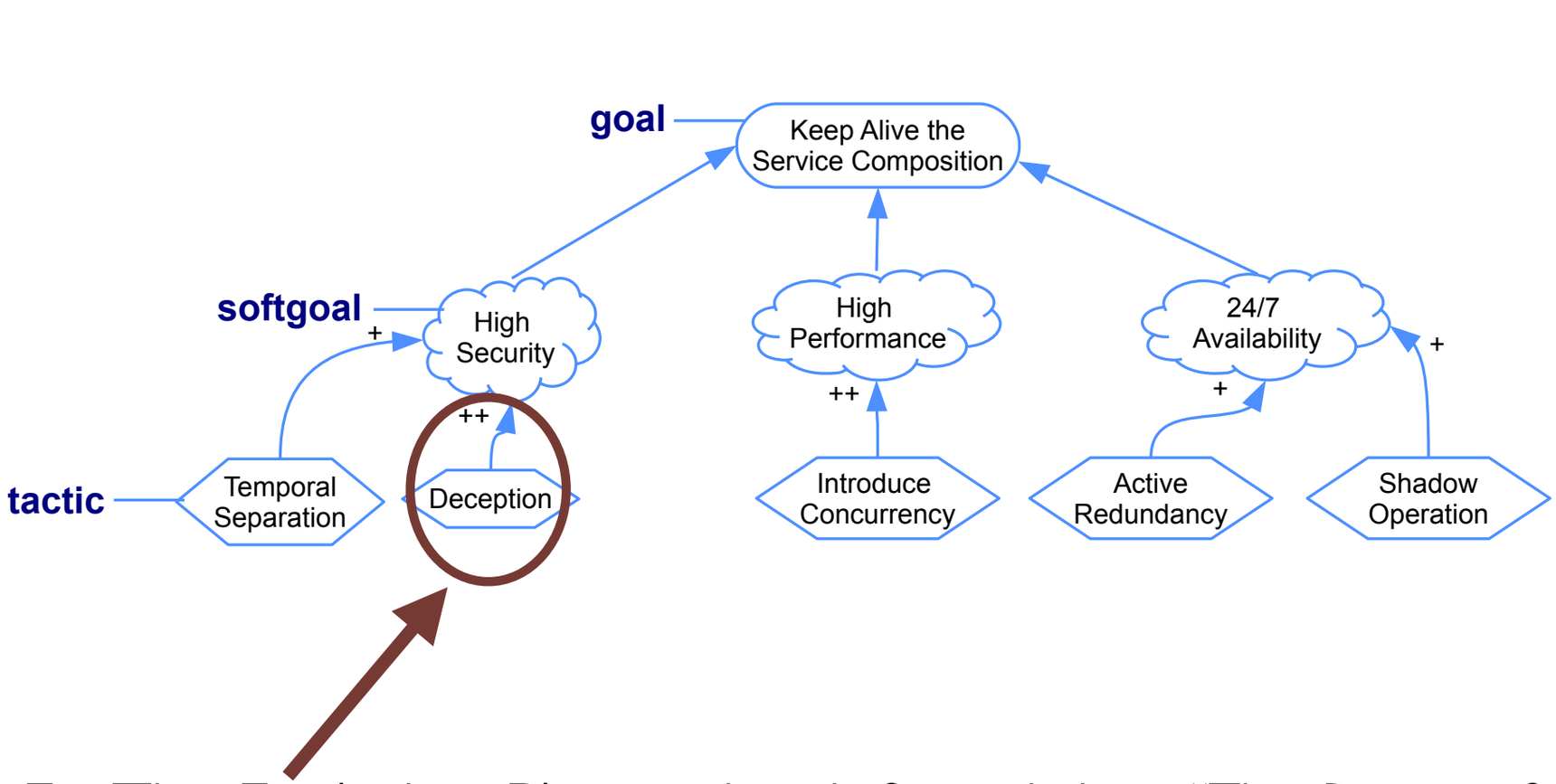
Forward chaining. This method evaluates arising context facts (i.e., context events) against general rule premises in the knowledge base. **New context events can trigger new inferences!**

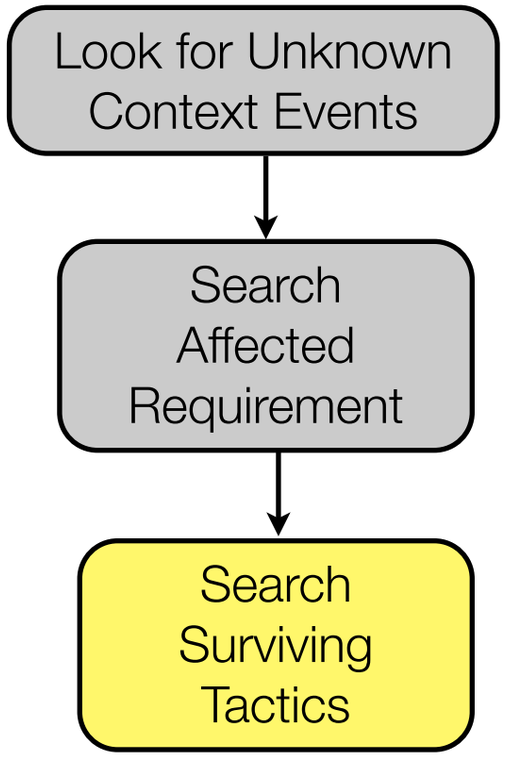


Alférez and Pelechano, **MODELS** 2012;
Alférez and Pelechano, **ICWS** 2013.

Evolution Planner

3) **Search Surviving Tactics:**



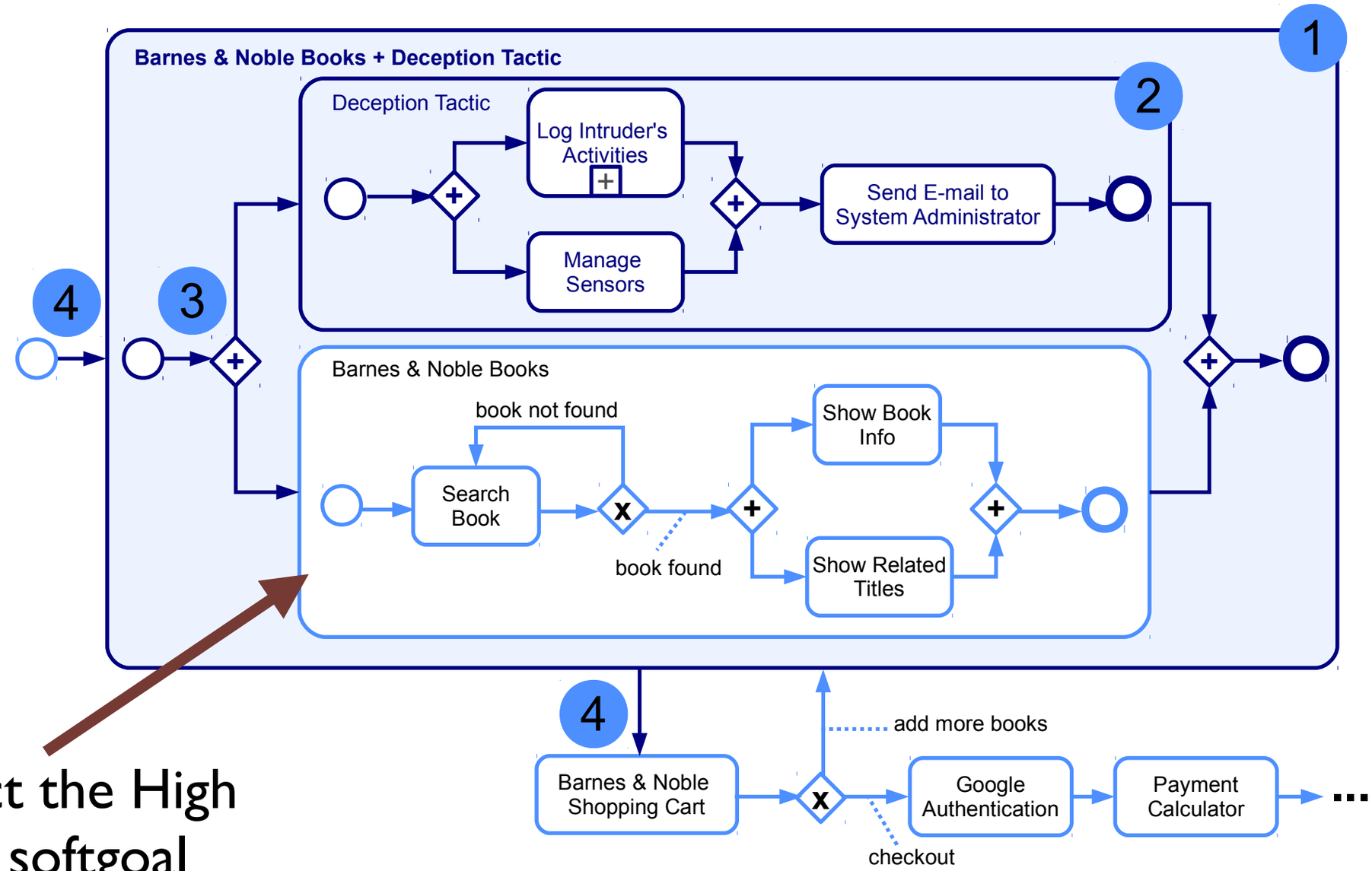


E.g. The Evolution Planner has inferred that *"The Barnes & Noble Books service operation can affect the High Security softgoal"*

Solution - Achieving Dynamic Evolution through Models at Runtime

Reconfiguration Engine

1) Merge a Tactic Model into the Composition Model:

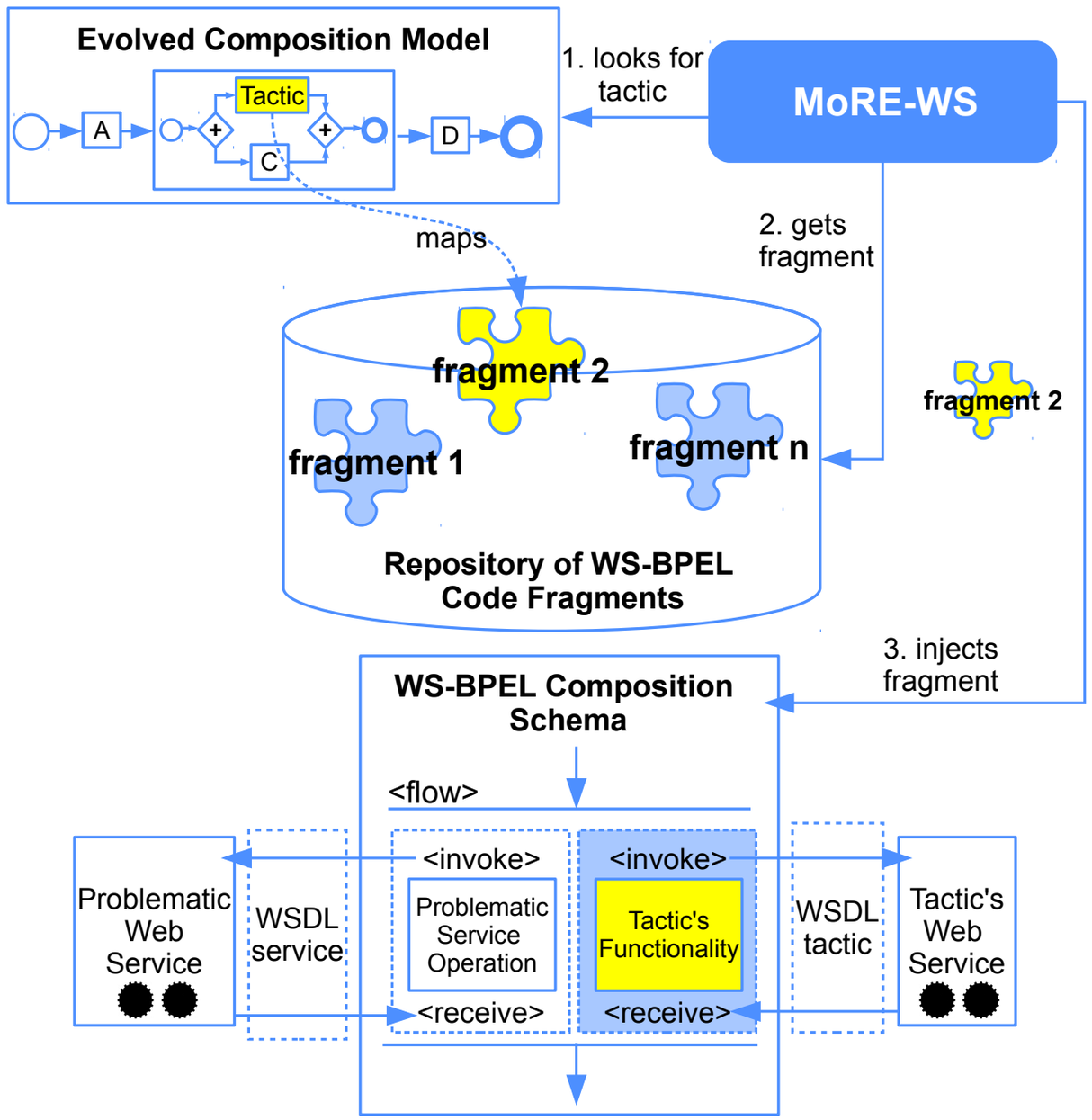


It can affect the High Security softgoal

Solution - Achieving Dynamic Evolution through Models at Runtime

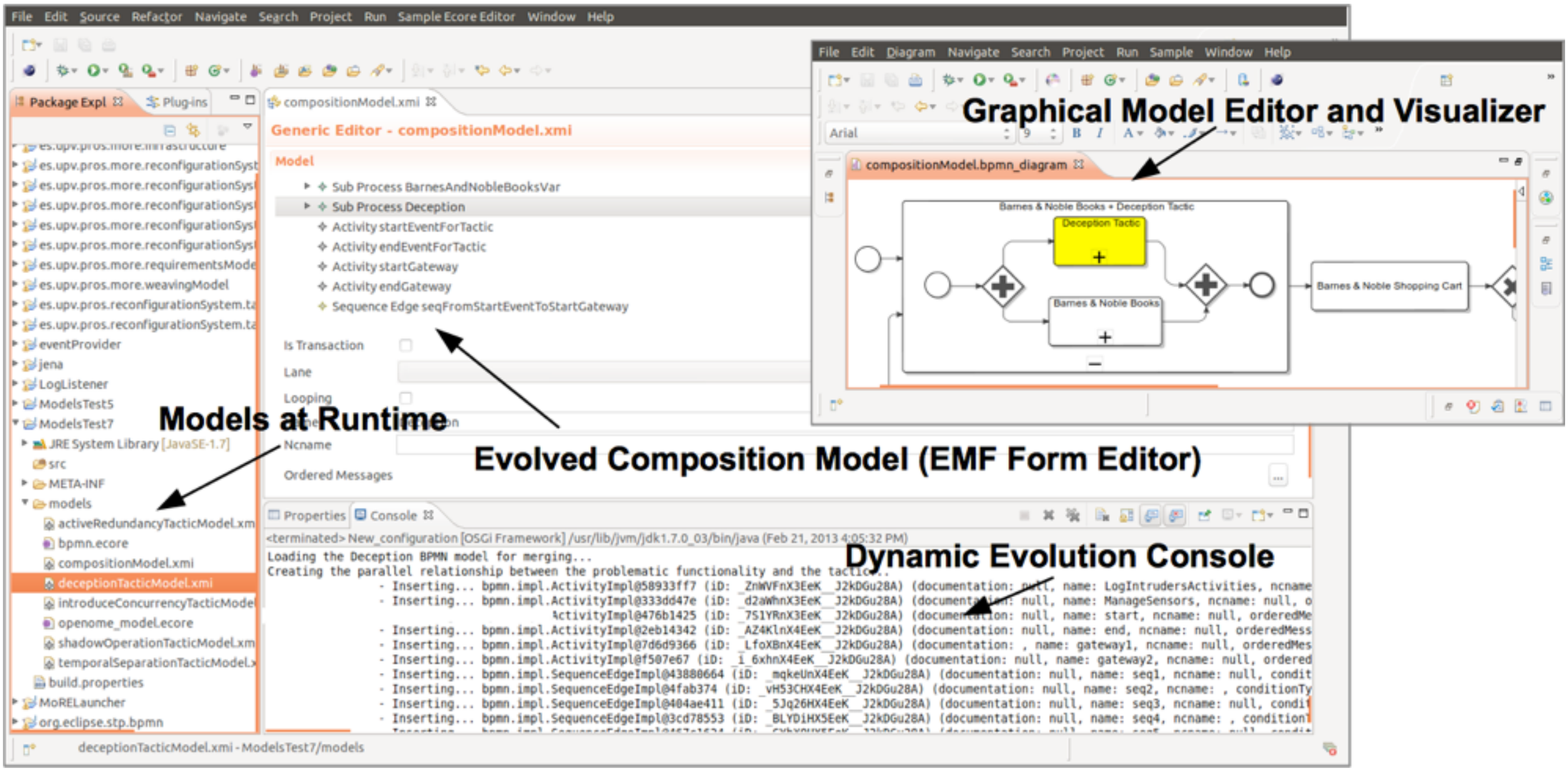
Reconfiguration Engine

2) **Evolve the WS-BPEL Composition Schema:**



Solution - Achieving Dynamic Evolution through Models at Runtime

Prototype



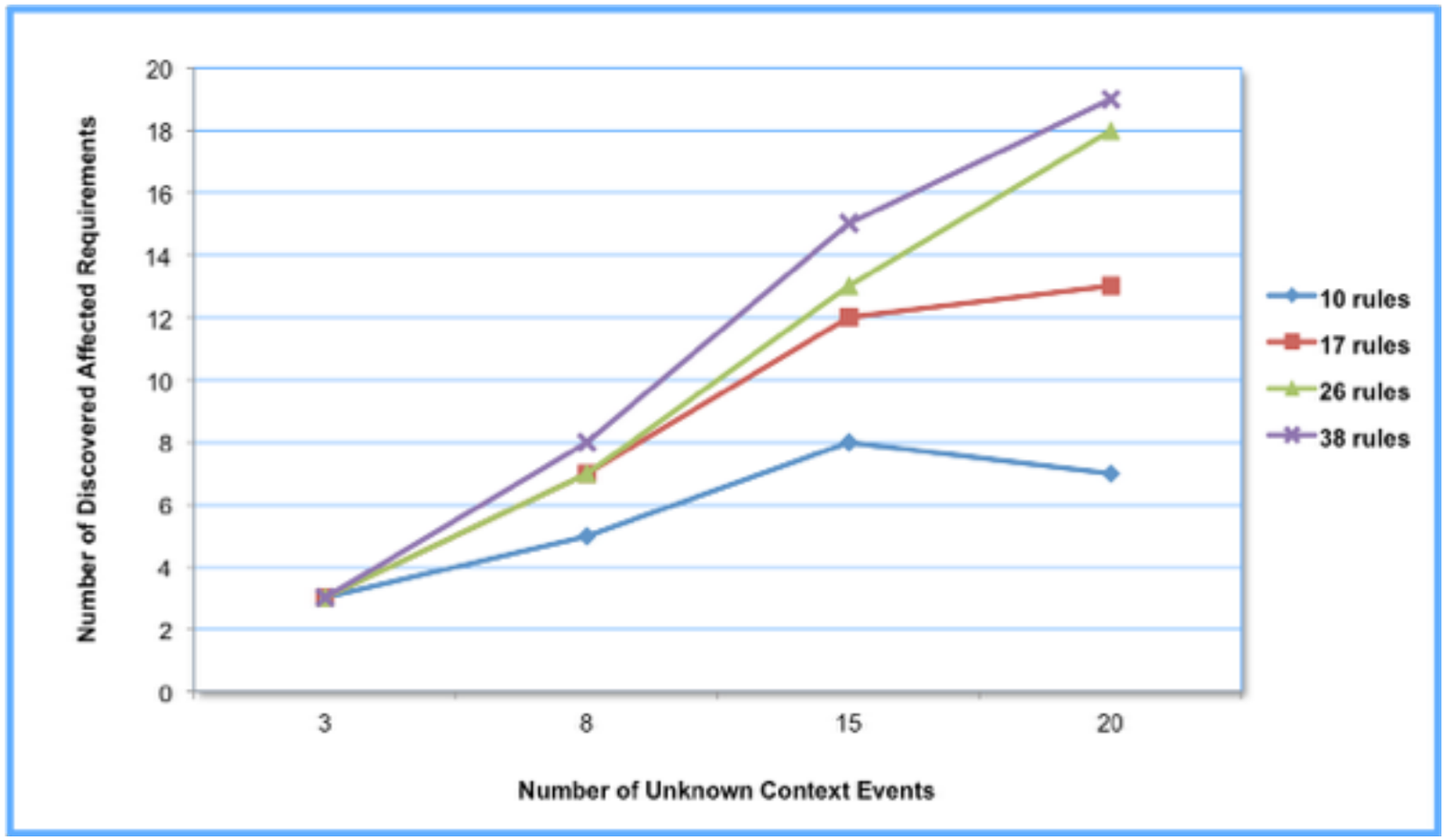
http://www.harveyalferez.com/dynamicevolutionservcomp/

Preliminary Results

Inferences Accuracy

- We purposely injected **a set of context events that were not predefined at design time**.

- Our approach found the affected requirements in **83.9%** cases.



The number of discovered requirements that can be negatively affected is directly proportional to the number of rules.

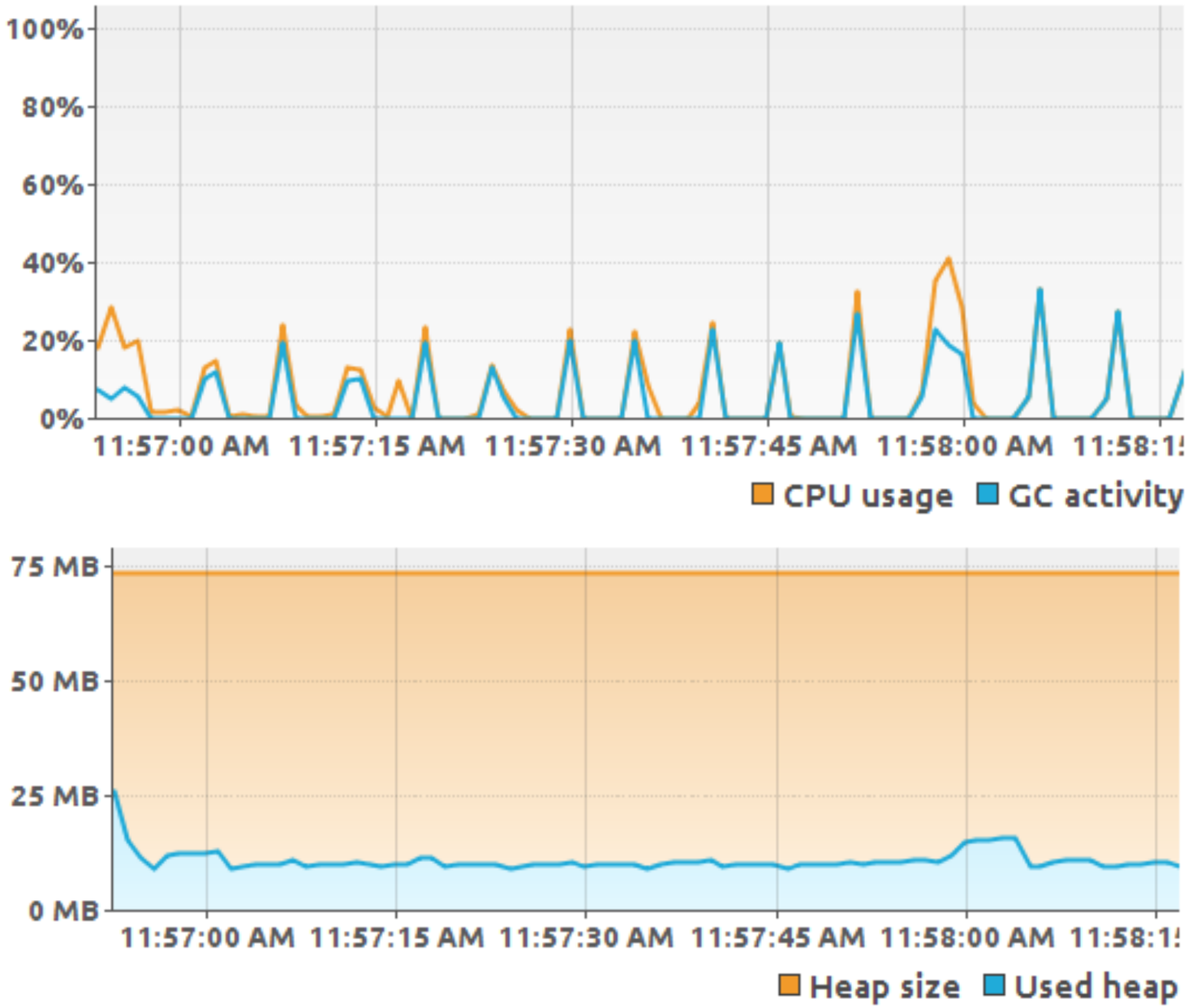
Reduced Uncertainty

Validation

Dynamic Evolution Efficiency

Measures during **a dynamic evolution**.

Efficient Dynamic Evolution



Validation

Conclusions and Future Work

- A **tool-supported approach** that leverages **models at runtime** to guide the **dynamic evolution** of **context-aware service compositions** in the **open world**.
- It covers **design time** and **runtime**.
- It can be used to **manage uncertainty** produced by **unknown context events**.

- The use of **models at runtime** has the following **benefits**:
  - The modeling effort made at design time also provides a rich semantic base for autonomic behavior during execution.
  - They provide up-to-date information to drive subsequent evolutions.
  - Technological bridges are avoided.

- Use **Constraint Programming** to **verify** the evolved models and check that generated configurations respect the constraints imposed by the models.

- Carry out **proactive** dynamic evolutions with **machine learning**.

- Apply the approach in other **domains:**

  - Robotics
  - Smart Cities
  - Wearables
  - Cloud Computing
  - The Internet of Things

Thanks!

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