UNIVERSIDAD
POLITECNICA
DE VALENCIA

PROS
Centro de Investigación en Métodos
de Producción de Software

MINISTERIO
DE CIENCIA
E INNOVACIÓN

Context-Aware Autonomous Web Services in Software Product Lines

Germán H. Alférez[1] and Vicente Pelechano[2]

1 Facultad de Ingeniería y Tecnología, Universidad de Montemorelos, Mexico

2 Centro de Investigación en Métodos de Producción de Software (ProS), Universitat Politècnica de València, Spain

Presented at the 15th International Software Product Line Conference (SPLC).

Munich, Germany. August, 2011

Context of the Problem

Service-Oriented Architecture:

Improves the **agility** and **cost-effectiveness** of a company.

Web services are the most common realization of SOA:

Run in heterogeneous and complex environments.

➔ **Adaptation mechanisms:**
- Impractical to assign manual reconfiguration tasks.
  - *Burden to IT staff* & *reaction to contextual events*.
- Autonomic Computing: self-* mechanisms.
  - *Dynamic binding* & *adaptation policies*.

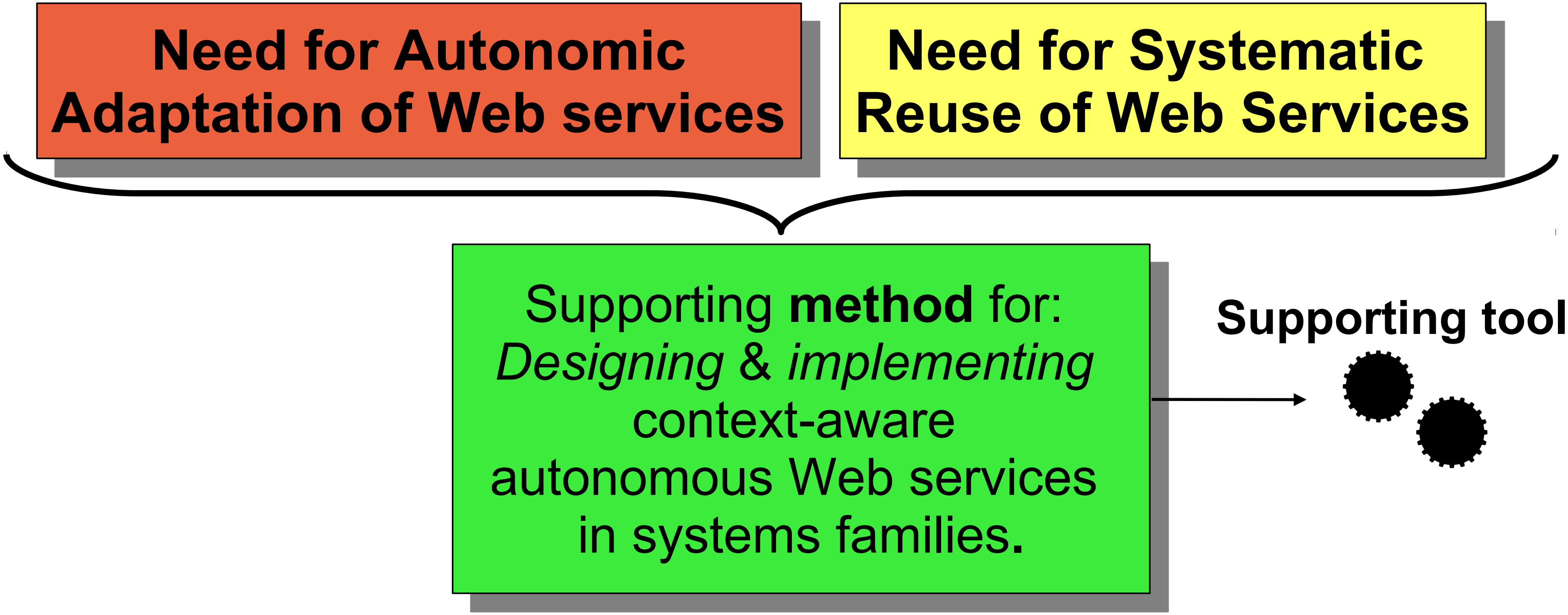
➔ **In SOA, reusability logic is divided into services.**
- SOA does not promote prescribed reuse of Web services.
- Variants among systems are difficult to capture explicitly using the notion of Web services.

Problem

Need for Autonomic Adaptation of Web services

Need for Systematic Reuse of Web Services

Our Approach



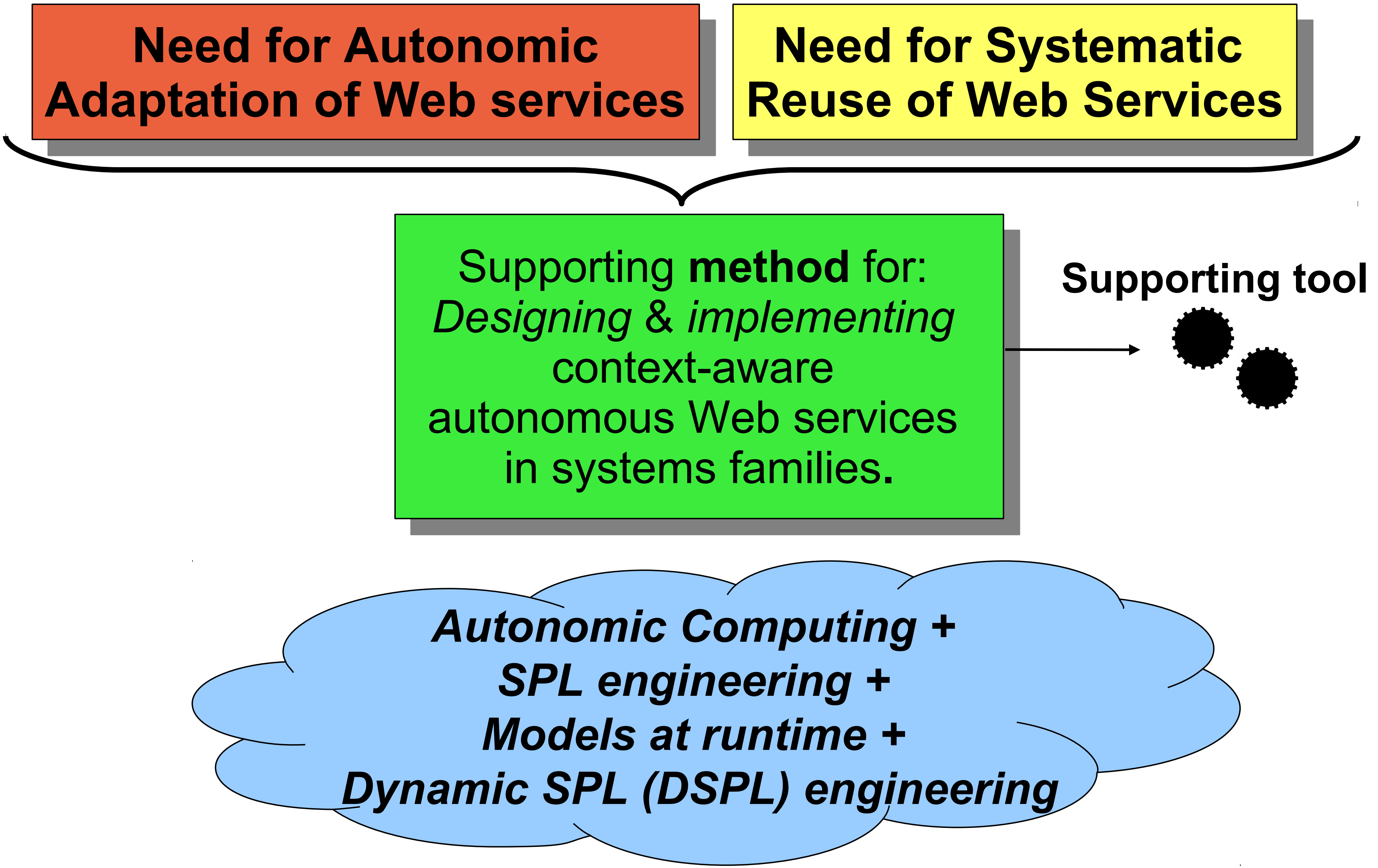
Need for Autonomic Adaptation of Web services

Need for Systematic Reuse of Web Services

Supporting **method** for:
Designing & *implementing*
context-aware
autonomous Web services
in systems families**.**

Supporting tool

Our Approach



Need for Autonomic Adaptation of Web services

Need for Systematic Reuse of Web Services

Supporting **method** for: *Designing* & *implementing* context-aware autonomous Web services in systems families.

Supporting tool

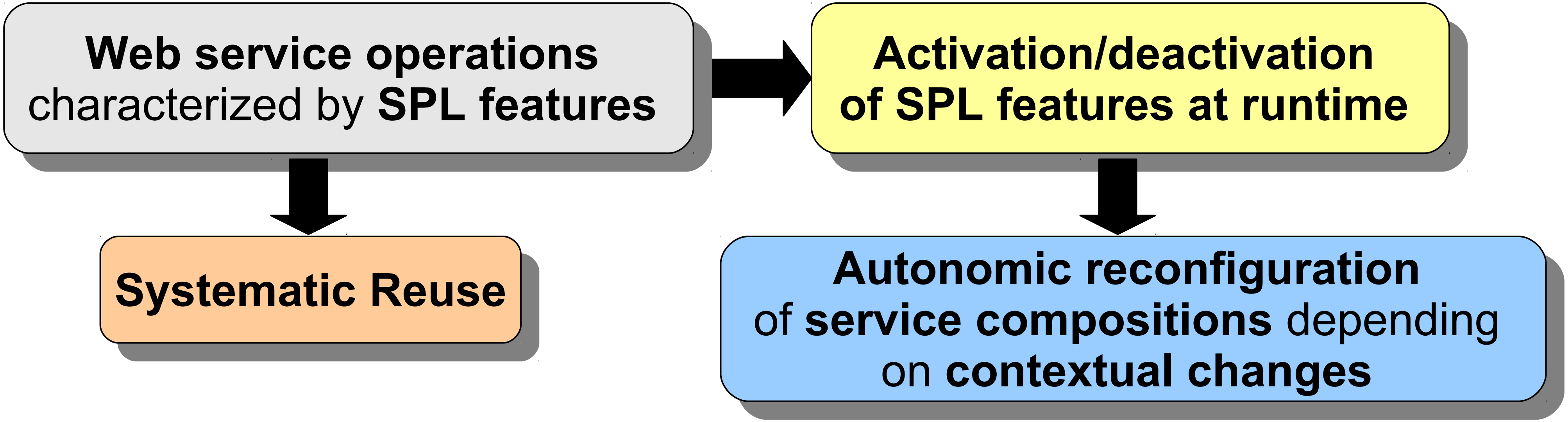
Autonomic Computing +
SPL engineering +
Models at runtime +
Dynamic SPL (DSPL) engineering

Our Approach

Our method's basis:

- **Autonomic Computing:** Automate tasks for self-adapting Web service operations.

- **SPL Engineering:**



Web service operations characterized by **SPL features**

Activation/deactivation of SPL features at runtime

Systematic Reuse

Autonomic reconfiguration of **service compositions** depending on **contextual changes**

Our Approach

Our method's basis (Cont.):

➔ **DSPL Engineering:** The architecture of a DSPL allows a flexible service recomposition.

- When features are activated/deactivated
  - A DSPL architecture binds variation points at runtime

➔ **Models at Runtime:** The *production capability* is based on reusable models (core assets).

- **Variability models**: Easy-to-understand and semantically rich ***adaptation policies*** for decision making.

Our Approach

Requirements:

1. Context: Any environmental information that can be used by a Web service at runtime.

2. Measure Instruments:

- **Monitor** the context and get the **measures** for basic **metrics** of specific **quality attributes**.
- **Availability** and **time**.

Our Approach

Requirements (Cont.):

3. Context Conditions:

- New context event → **Does it violate any context condition (Service Level Agreement or contract)?**
  - **Contract is violated** → **Reconfiguration** of the service composition.

4. Resolutions:

- If a **context condition** has been accomplished: **What are we going to do?**
- Express **adaptation policies** or **transitions** between different configurations of service compositions.
- $R_C = \{(F, S)\} \mid F \in [FM] \wedge S \in \{Active, Inactive\}$

Our Approach

Our method's SPL activities:

1. Domain Engineering Activity.

- ➔ **Reusable models:** Production capability for service compositions.

2. Application Engineering Activity.

- ➔ Supports the **derivation of specific service compositions from a product family**.
- ➔ Autonomic recomposing Web services: **Model-based Reconfiguration Engine for Web services (MoRE-WS)**.

Our Approach

MoRE-WS:

→ MoRE-WS **translates context changes** into **changes in the activation/deactivation of features**.

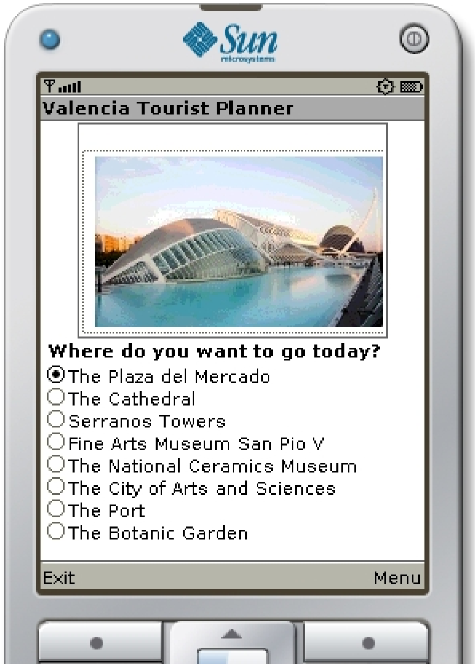
→ ***Our previous work:*** C. Cetina, P. Giner, J. Fons, and V. Pelechano, "Autonomic computing through reuse of variability models at runtime: The case of smart homes," Computer, vol. 42, pp. 37-43, October 2009.

Our Approach

Case Study:

A SPL for **mobile tourist planners** based on Web services:

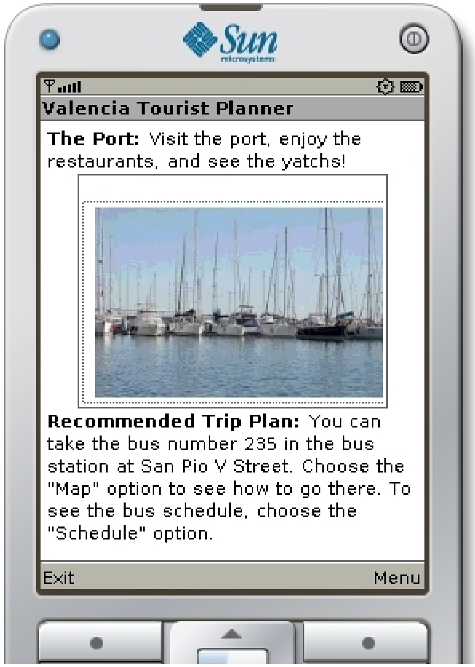
- Lists the tourist attractions of a city.
- Recommends trips to those places depending on the **weather** and **current location**.



Valencia Tourist Planner

Where do you want to go today?

● The Plaza del Mercado
○ The Cathedral
○ Serranos Towers
○ Fine Arts Museum San Pio V
○ The National Ceramics Museum
○ The City of Arts and Sciences
○ The Port
○ The Botanic Garden



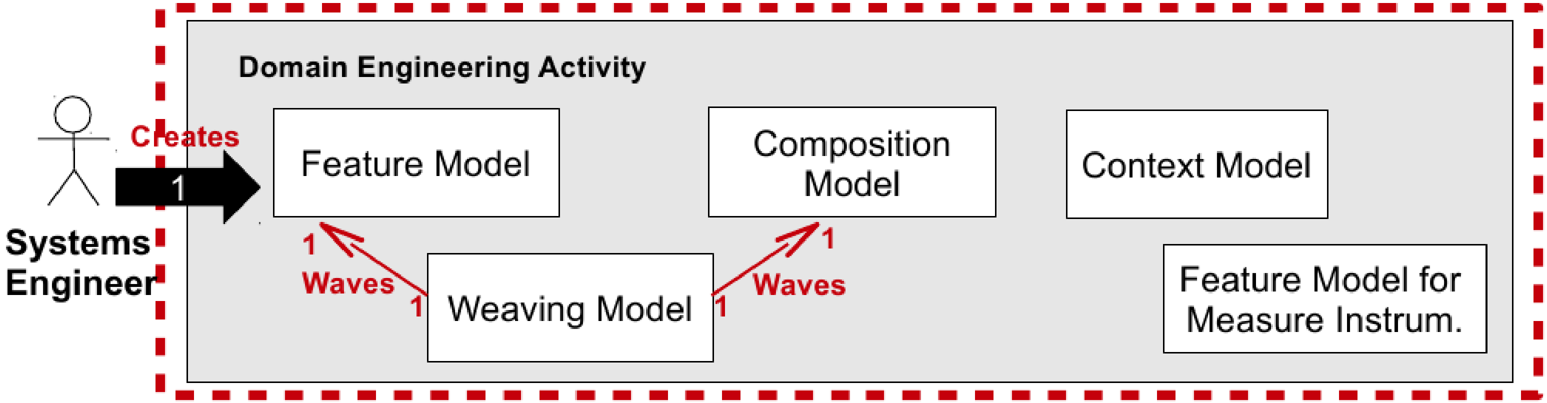
Valencia Tourist Planner

The Port: Visit the port, enjoy the restaurants, and see the yatchs!

Recommended Trip Plan: You can take the bus number 235 in the bus station at San Pio V Street. Choose the "Map" option to see how to go there. To see the bus schedule, choose the "Schedule" option.

Our Approach

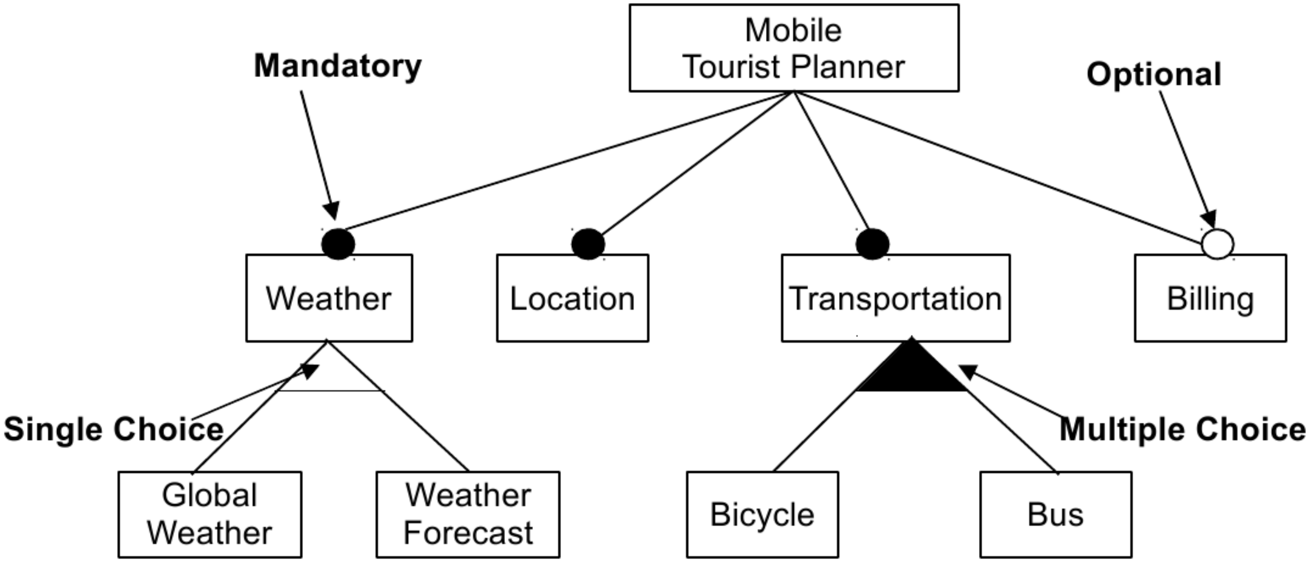
Domain Engineering Activity:



Our Approach

Domain Engineering Activity / Feature Model:

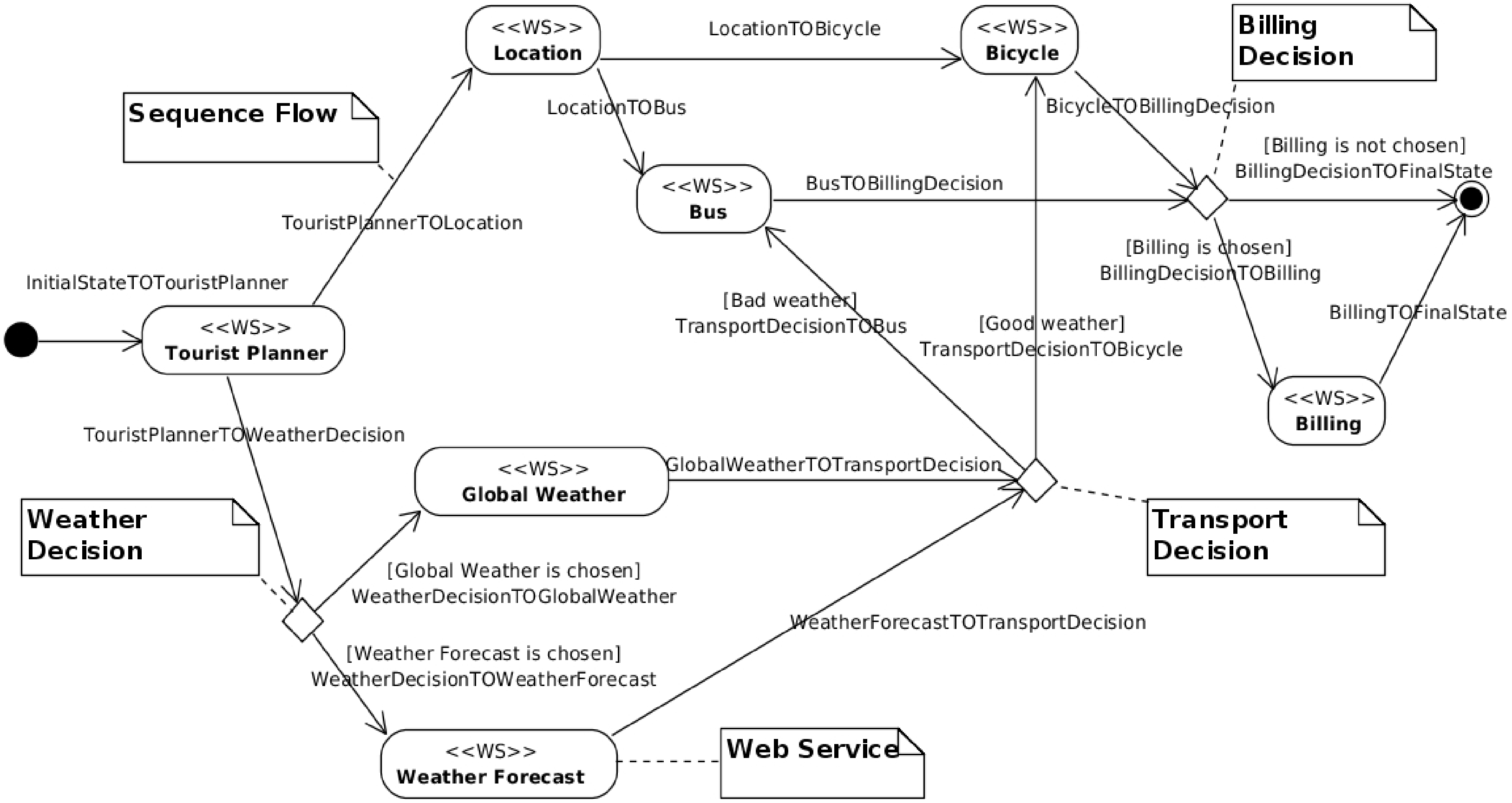
- Describes the **dynamic system configurations** and the **variants** of the system.
- Some **features** denote the **initial system configuration**, while other features represent **potential variants**.



Our Approach

Domain Engineering Activity / Composition Model:

- **Web services** and the **sequence flows** among them.
- UML Activity diagram.

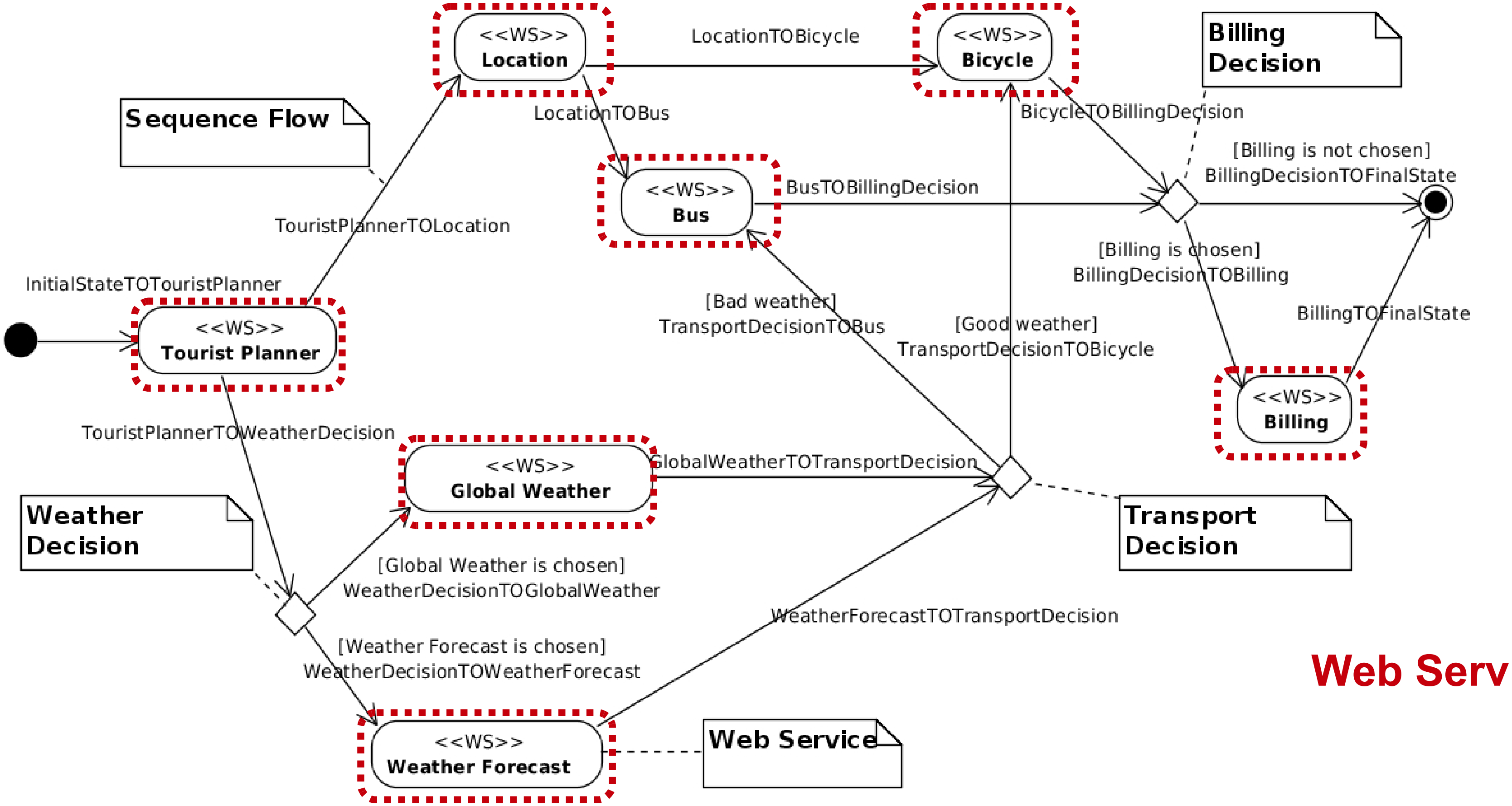


Sequence Flow
<<WS>> Location
LocationTOBicycle
<<WS>> Bicycle
Billing Decision
LocationTOBus
BicycleTOBillingDecision
[Billing is not chosen] BillingDecisionTOFinalState
<<WS>> Bus
BusTOBillingDecision
TouristPlannerTOLocation
[Billing is chosen] BillingDecisionTOBilling
InitialStateTOTouristPlanner
[Bad weather] TransportDecisionTOBus
[Good weather] TransportDecisionTOBicycle
BillingTOFinalState
<<WS>> Tourist Planner
<<WS>> Billing
TouristPlannerTOWeatherDecision
<<WS>> Global Weather
GlobalWeatherTOTransportDecision
Weather Decision
Transport Decision
[Global Weather is chosen] WeatherDecisionTOGlobalWeather
WeatherForecastTOTransportDecision
[Weather Forecast is chosen] WeatherDecisionTOWeatherForecast
<<WS>> Weather Forecast
Web Service

Our Approach

Domain Engineering Activity / Composition Model:

- **Web services** and the **sequence flows** among them.
- UML Activity diagram.

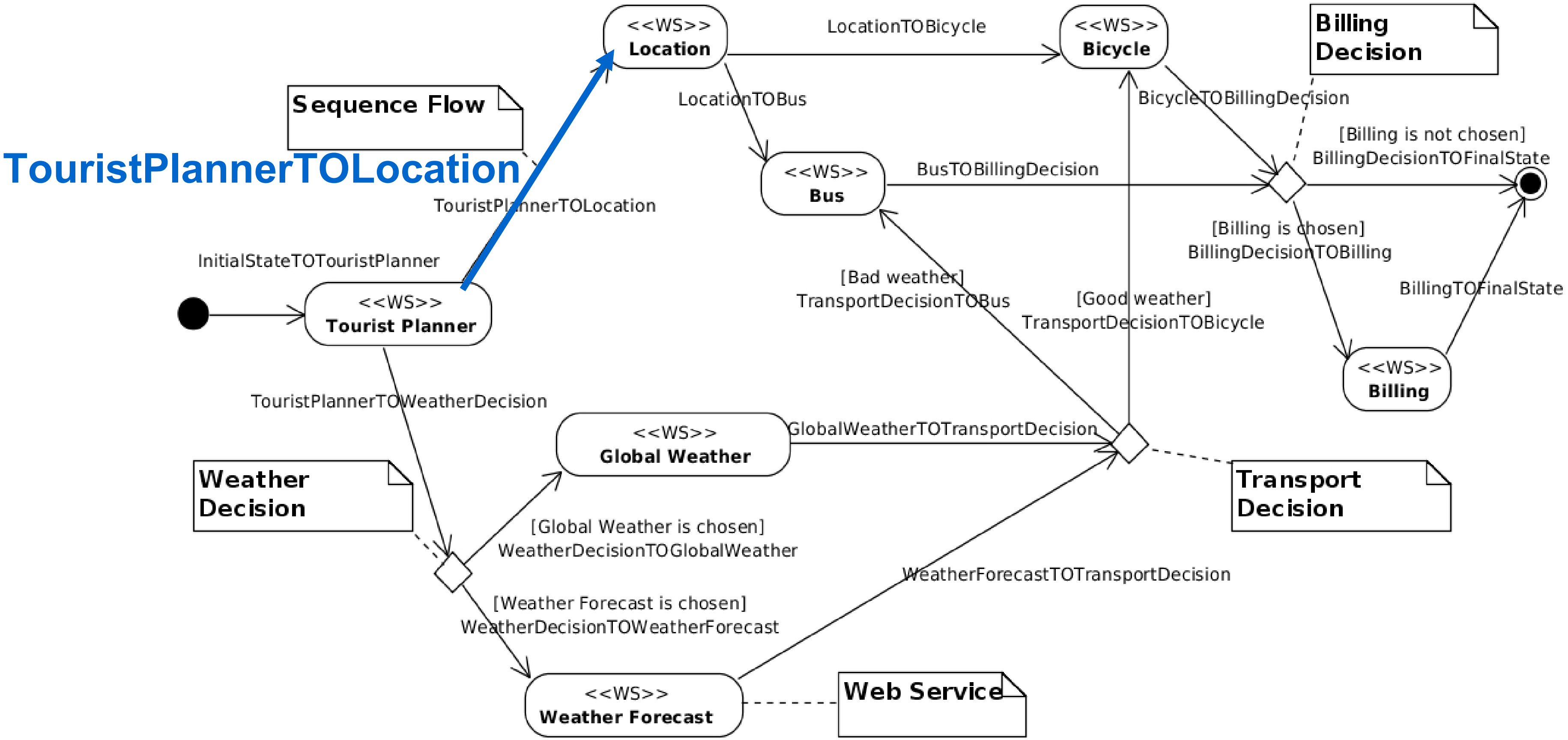


Web Services

Our Approach

Domain Engineering Activity / Composition Model:

- **Web services** and the **sequence flows** among them.
- UML Activity diagram.



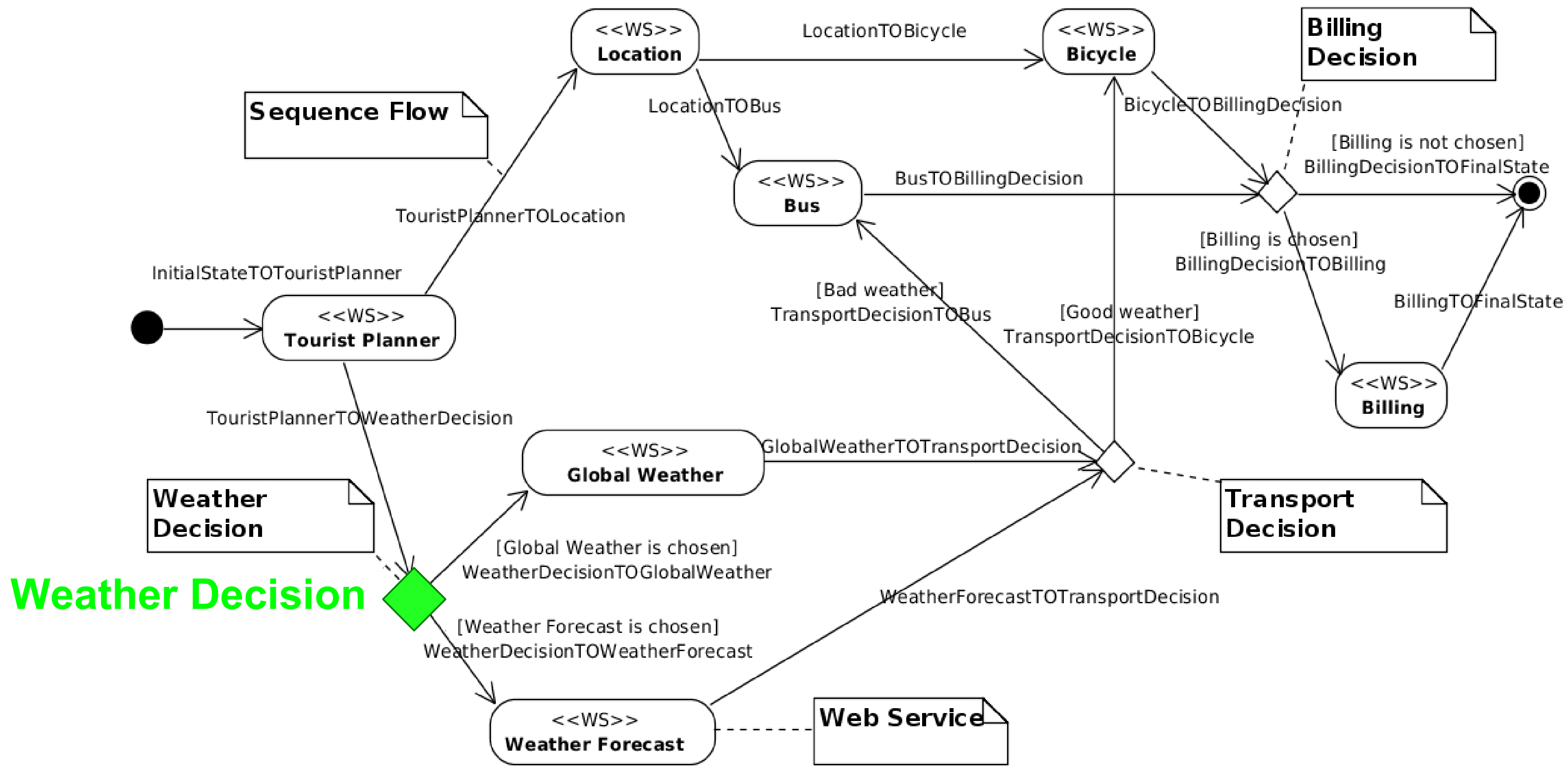
TouristPlannerTOLocation

<<WS>> Location
LocationTOBicycle
<<WS>> Bicycle
Billing Decision
Sequence Flow
LocationTOBus
BicycleTOBillingDecision
[Billing is not chosen] BillingDecisionTOFinalState
<<WS>> Bus
BusTOBillingDecision
TouristPlannerTOLocation
[Billing is chosen] BillingDecisionTOBilling
InitialStateTOTouristPlanner
[Bad weather] TransportDecisionTOBus
[Good weather] TransportDecisionTOBicycle
BillingTOFinalState
<<WS>> Tourist Planner
<<WS>> Billing
TouristPlannerTOWeatherDecision
<<WS>> Global Weather
GlobalWeatherTOTransportDecision
Weather Decision
Transport Decision
[Global Weather is chosen] WeatherDecisionTOGlobalWeather
WeatherForecastTOTransportDecision
[Weather Forecast is chosen] WeatherDecisionTOWeatherForecast
<<WS>> Weather Forecast
Web Service

Our Approach

Domain Engineering Activity / Composition Model:

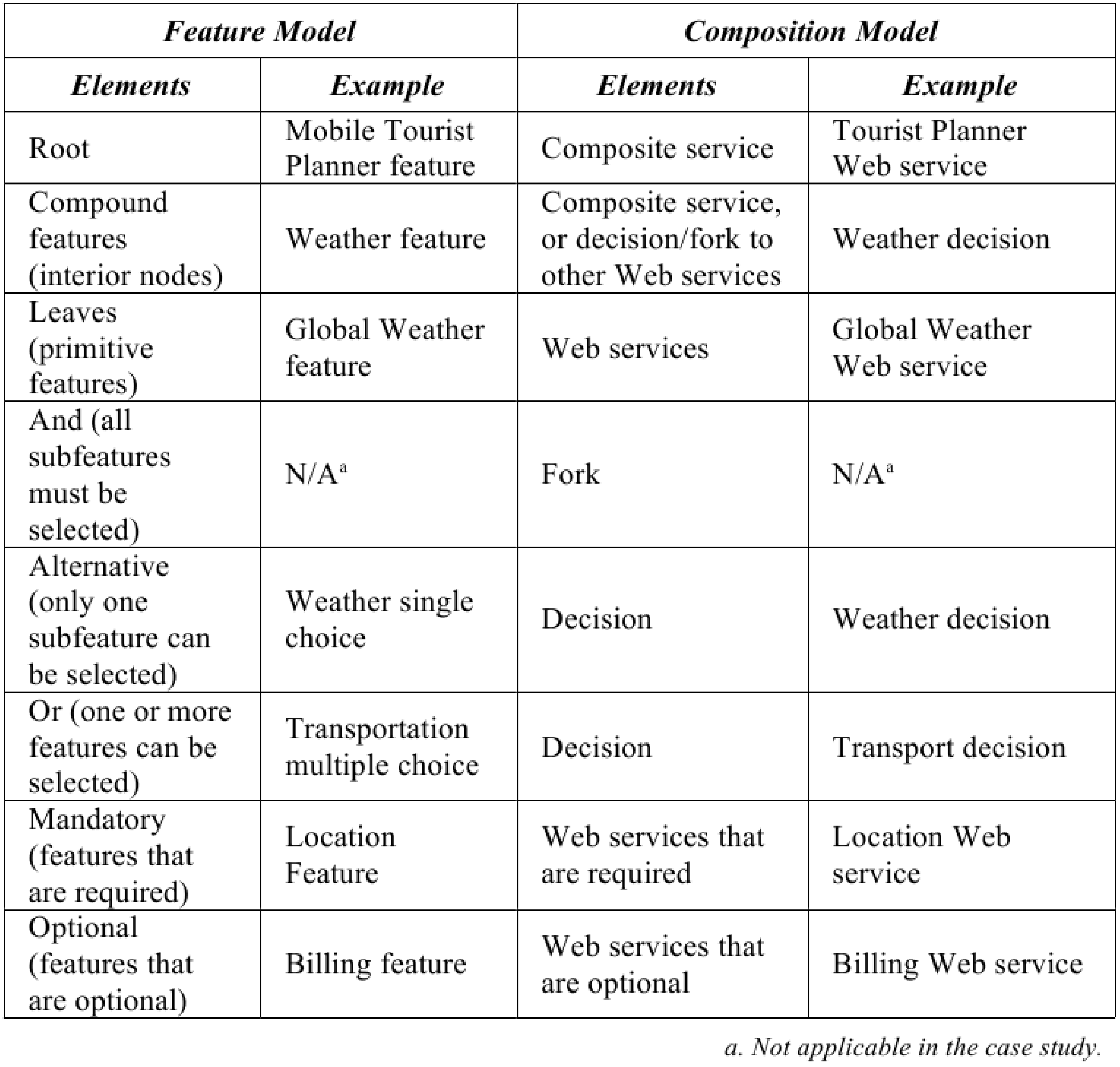
- **Web services** and the **sequence flows** among them.
- UML Activity diagram.


Sequence Flow
Billing Decision
Weather Decision
Transport Decision
Web Service
Weather Decision
<<WS>> Location
<<WS>> Bicycle
<<WS>> Bus
<<WS>> Tourist Planner
<<WS>> Billing
<<WS>> Global Weather
<<WS>> Weather Forecast
LocationTOBicycle
LocationTOBus
BicycleTOBillingDecision
BusTOBillingDecision
[Billing is not chosen] BillingDecisionTOFinalState
[Billing is chosen] BillingDecisionTOBilling
BillingTOFinalState
TouristPlannerTOLocation
InitialStateTOTouristPlanner
[Bad weather] TransportDecisionTOBus
[Good weather] TransportDecisionTOBicycle
TouristPlannerTOWeatherDecision
GlobalWeatherTOTransportDecision
[Global Weather is chosen] WeatherDecisionTOGlobalWeather
[Weather Forecast is chosen] WeatherDecisionTOWeatherForecast
WeatherForecastTOTransportDecision

Our Approach

Domain Engineering Activity / Composition Model:

Mapping rules.



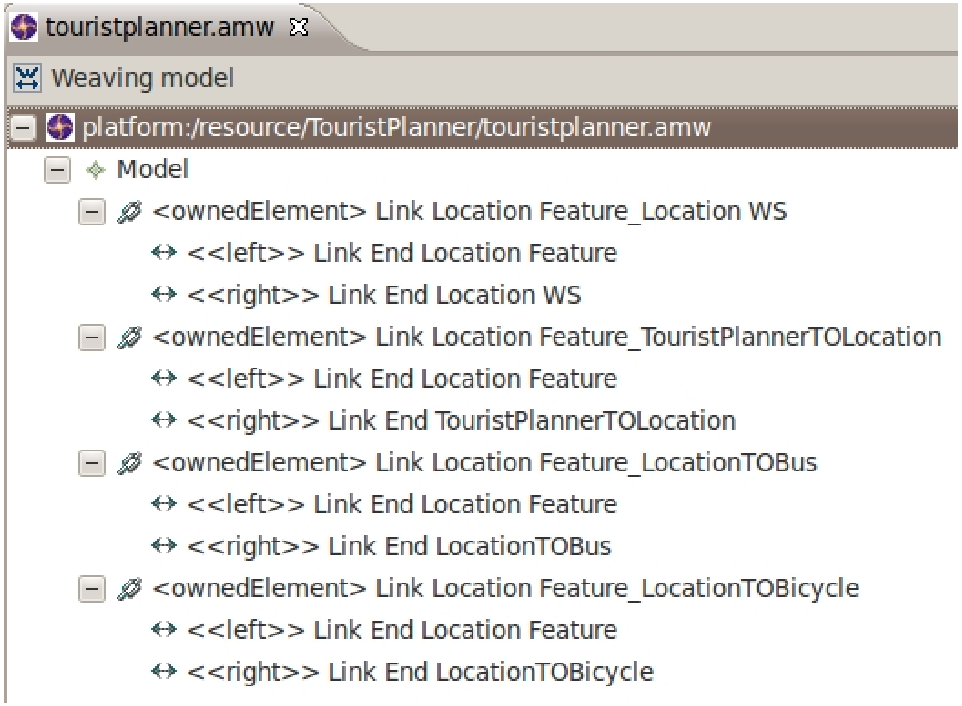
Feature Model		*Composition Model*	
Elements	***Example***	***Elements***	***Example***
Root	Mobile Tourist Planner feature	Composite service	Tourist Planner Web service
Compound features (interior nodes)	Weather feature	Composite service, or decision/fork to other Web services	Weather decision
Leaves (primitive features)	Global Weather feature	Web services	Global Weather Web service
And (all subfeatures must be selected)	N/A[a]	Fork	N/A[a]
Alternative (only one subfeature can be selected)	Weather single choice	Decision	Weather decision
Or (one or more features can be selected)	Transportation multiple choice	Decision	Transport decision
Mandatory (features that are required)	Location Feature	Web services that are required	Location Web service
Optional (features that are optional)	Billing feature	Web services that are optional	Billing Web service

a. Not applicable in the case study.

Our Approach

Domain Engineering Activity / Weaving Model:

- **Define** and **capture relationships** between **features** in the *Feature Model* and **model elements** of the *Composition Model*.
- One-to-many relationship.



touristplanner.amw

Weaving model

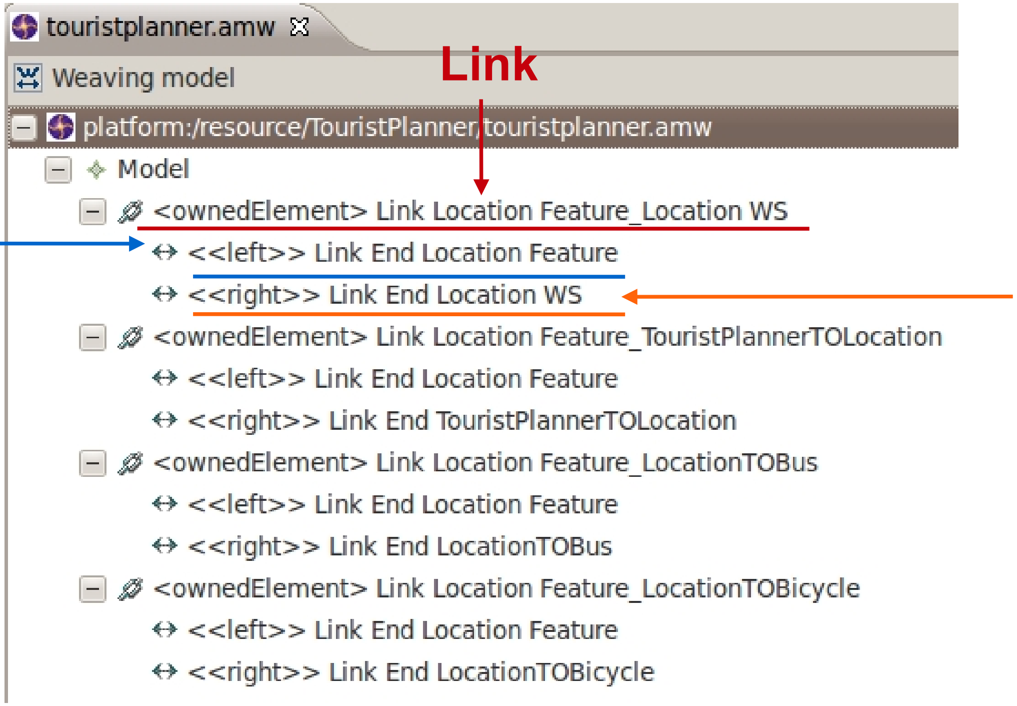
platform:/resource/TouristPlanner/touristplanner.amw

- Model
  - <ownedElement> Link Location Feature_Location WS
    - <<left>> Link End Location Feature
    - <<right>> Link End Location WS
  - <ownedElement> Link Location Feature_TouristPlannerTOLocation
    - <<left>> Link End Location Feature
    - <<right>> Link End TouristPlannerTOLocation
  - <ownedElement> Link Location Feature_LocationTOBus
    - <<left>> Link End Location Feature
    - <<right>> Link End LocationTOBus
  - <ownedElement> Link Location Feature_LocationTOBicycle
    - <<left>> Link End Location Feature
    - <<right>> Link End LocationTOBicycle

Our Approach

Domain Engineering Activity / Weaving Model:

- **Define** and **capture relationships** between **features** in the *Feature Model* and **model elements** of the *Composition Model*.
- One-to-many relationship.



Left Element: Location Feature

Link

Right Element: Location Web Service

touristplanner.amw

Weaving model

- platform:/resource/TouristPlanner/touristplanner.amw
  - Model
    - <ownedElement> Link Location Feature_Location WS
      - <<left>> Link End Location Feature
      - <<right>> Link End Location WS
    - <ownedElement> Link Location Feature_TouristPlannerTOLocation
      - <<left>> Link End Location Feature
      - <<right>> Link End TouristPlannerTOLocation
    - <ownedElement> Link Location Feature_LocationTOBus
      - <<left>> Link End Location Feature
      - <<right>> Link End LocationTOBus
    - <ownedElement> Link Location Feature_LocationTOBicycle
      - <<left>> Link End Location Feature
      - <<right>> Link End LocationTOBicycle

Our Approach

Domain Engineering Activity / Feature Model for Measure Instruments:

- **Measure instruments** in terms of **features**: e.g. Response time and execution time.
  - They can be **systematically reused.**

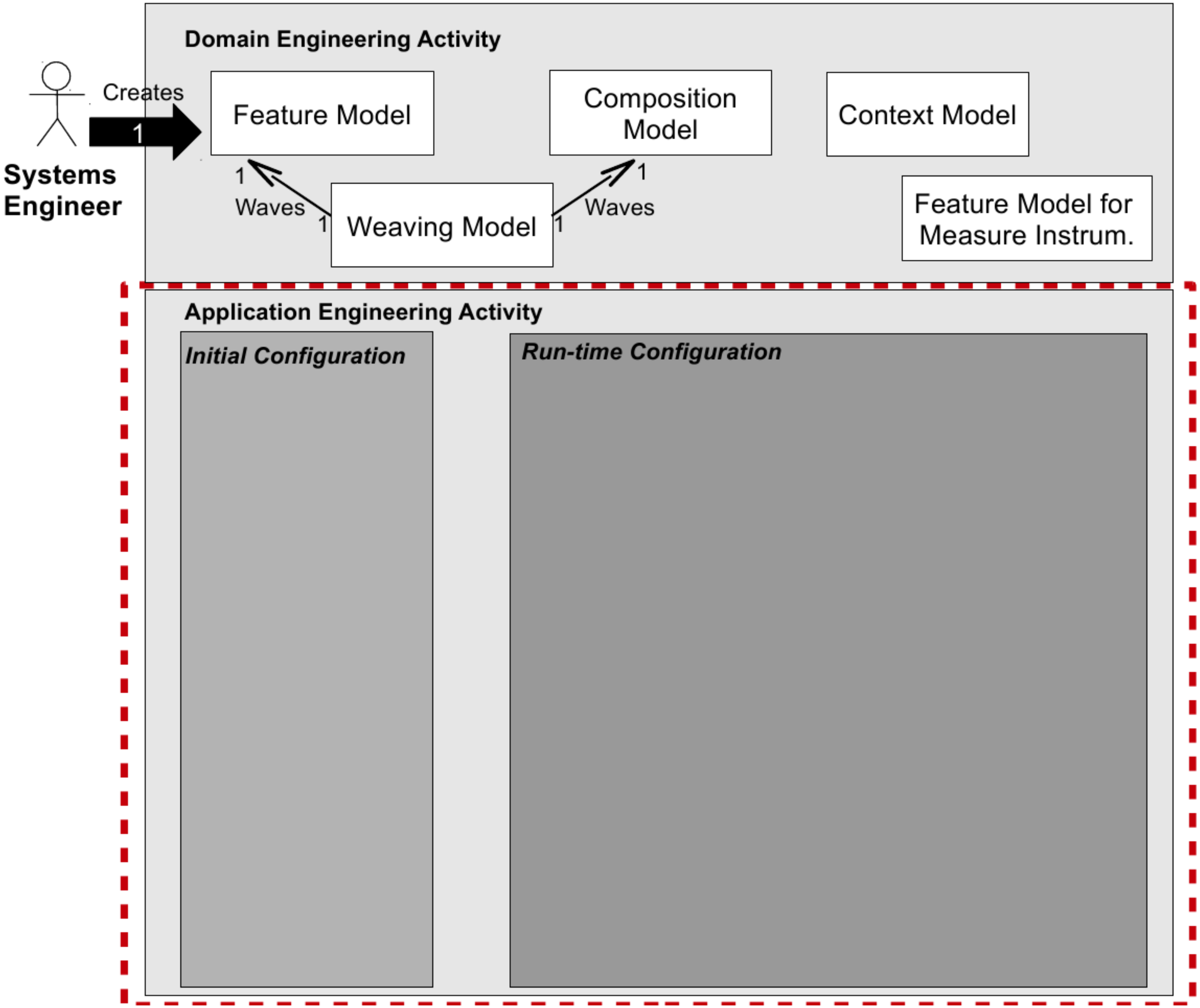
Our Approach

Domain Engineering Activity / Context Model:

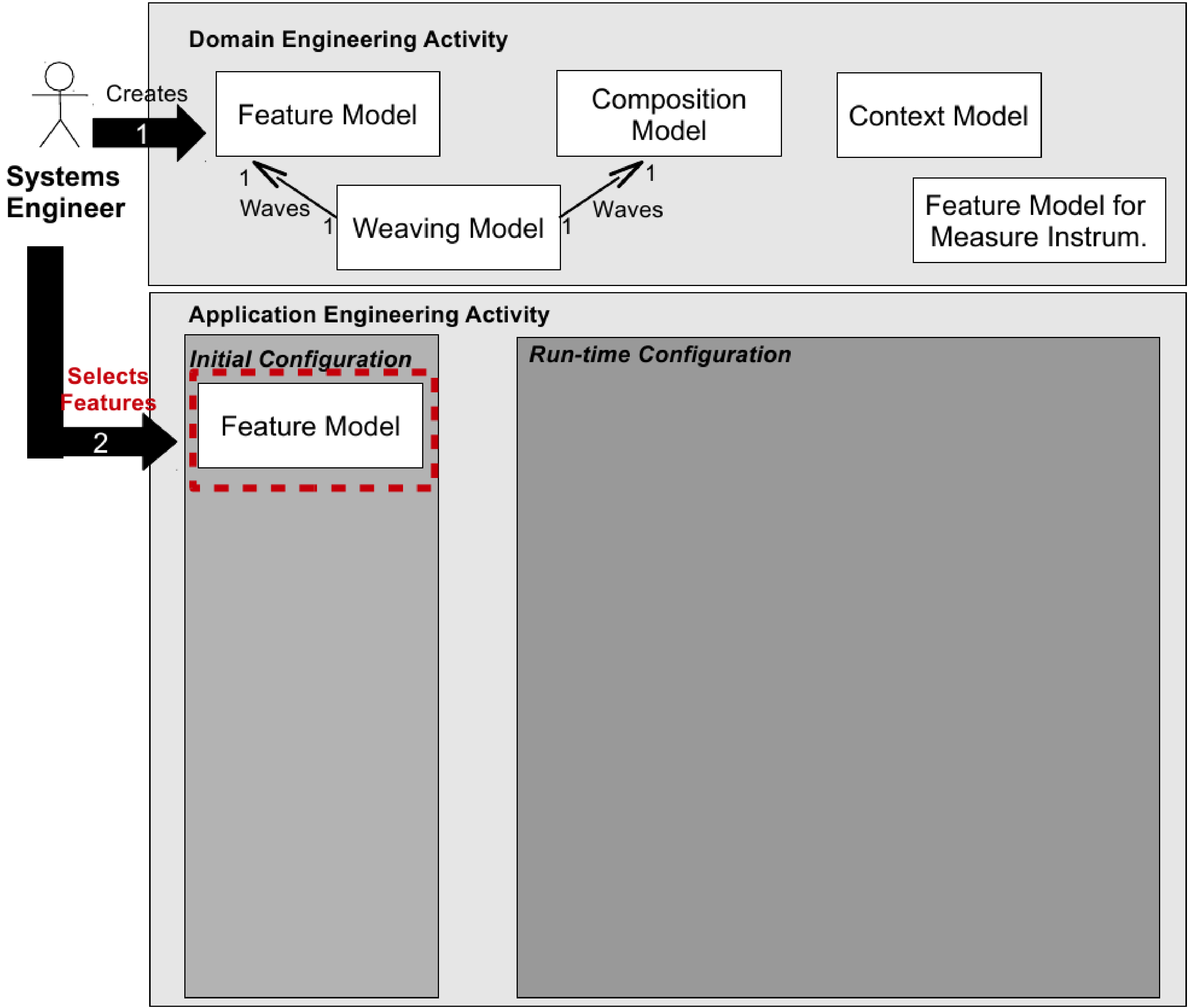
- **Ontology-based.**
  - **Formal analysis of the domain knowledge.** Context reasoning using first-order logic.

Our Approach

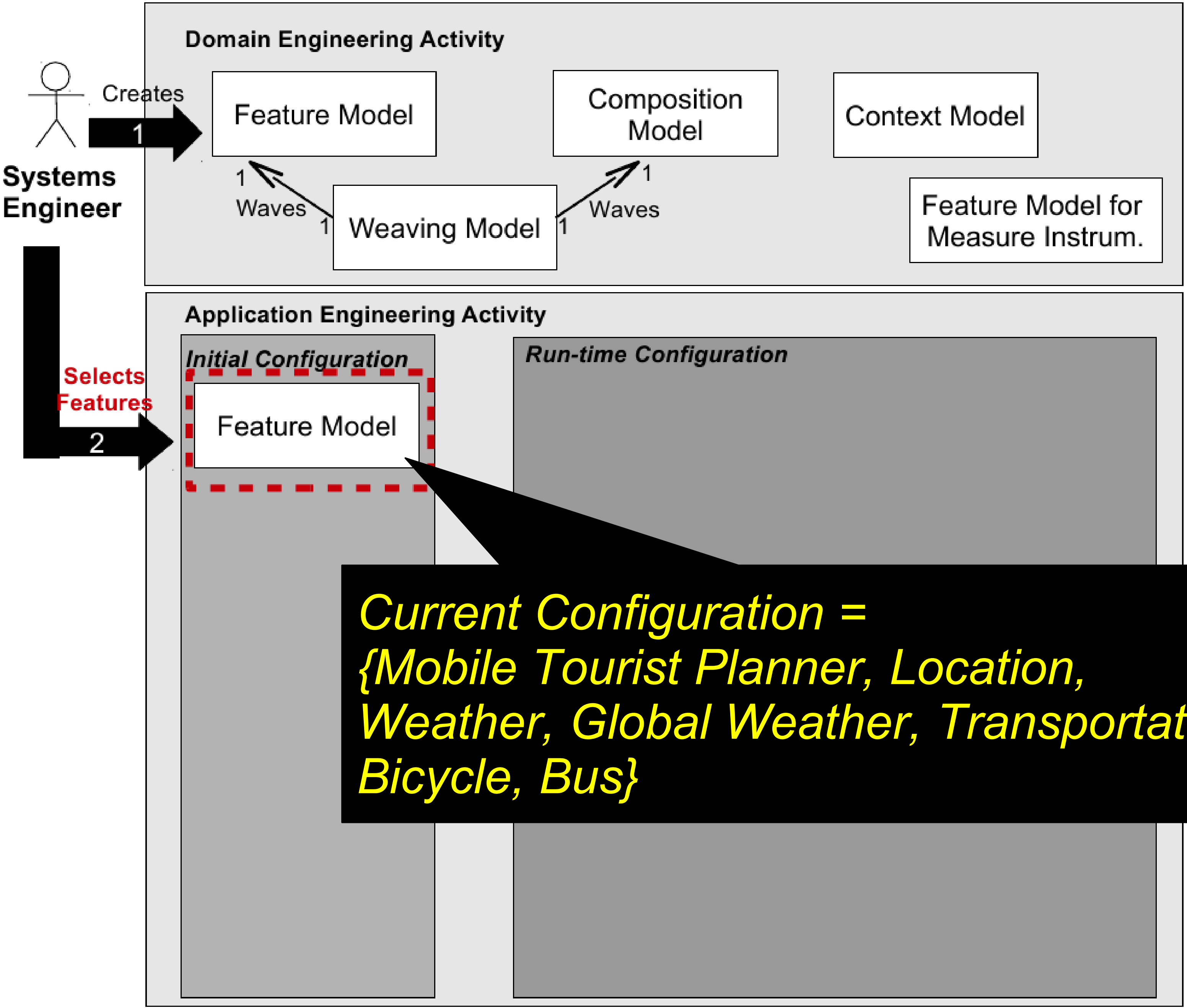
Application Engineering Activity:



Our Approach

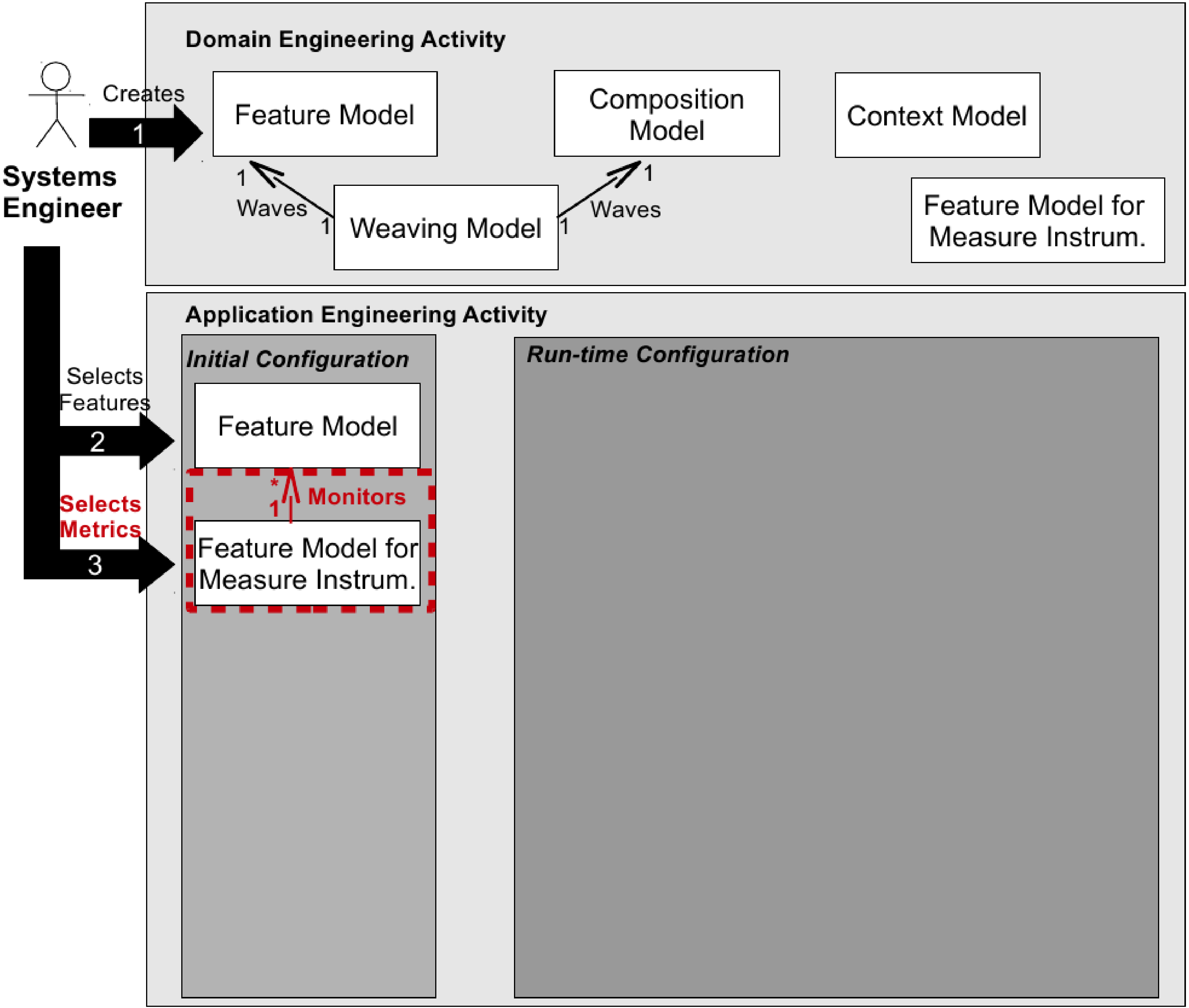


Our Approach

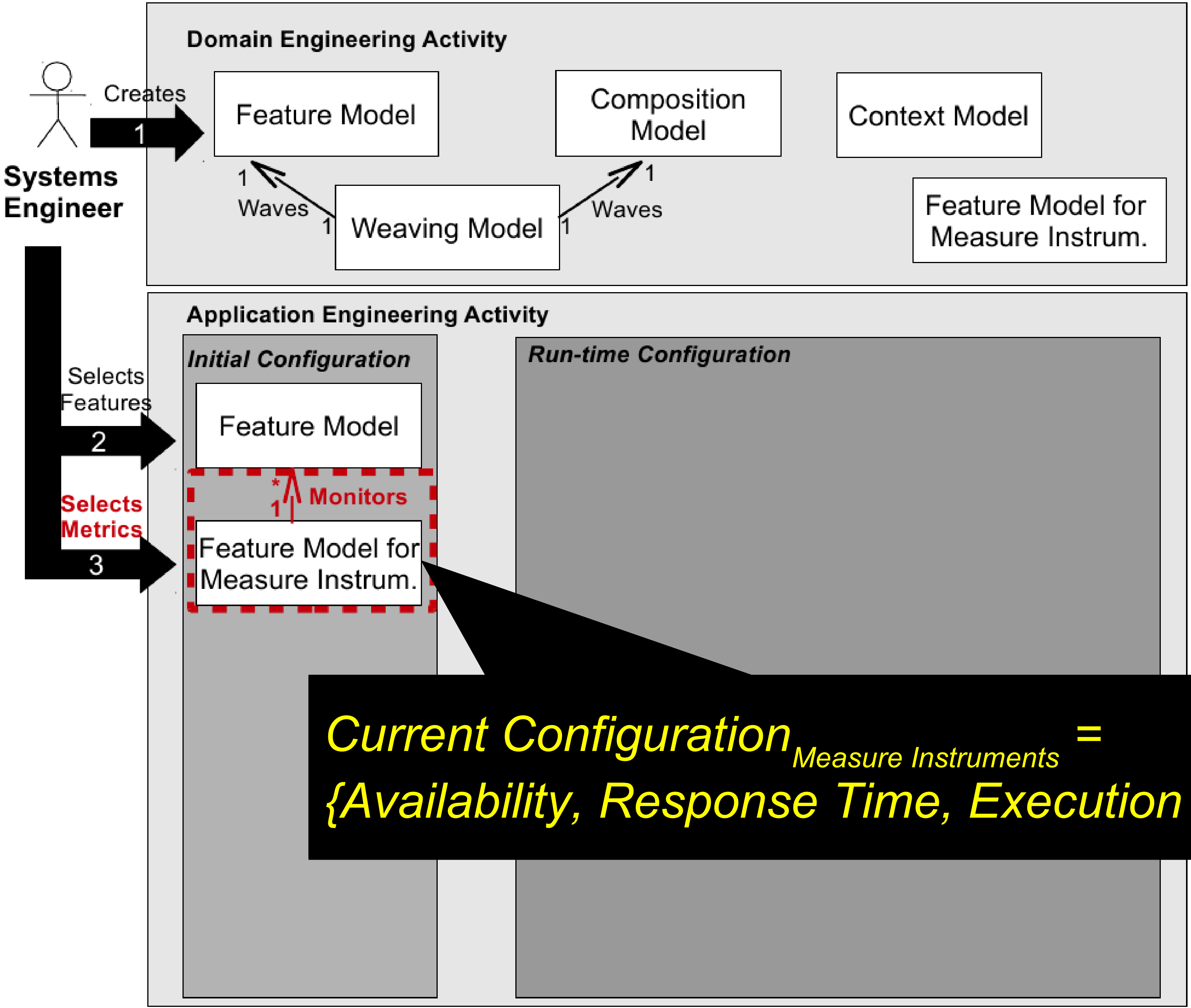


Current Configuration =
{Mobile Tourist Planner, Location, Weather, Global Weather, Transportation, Bicycle, Bus}

Our Approach

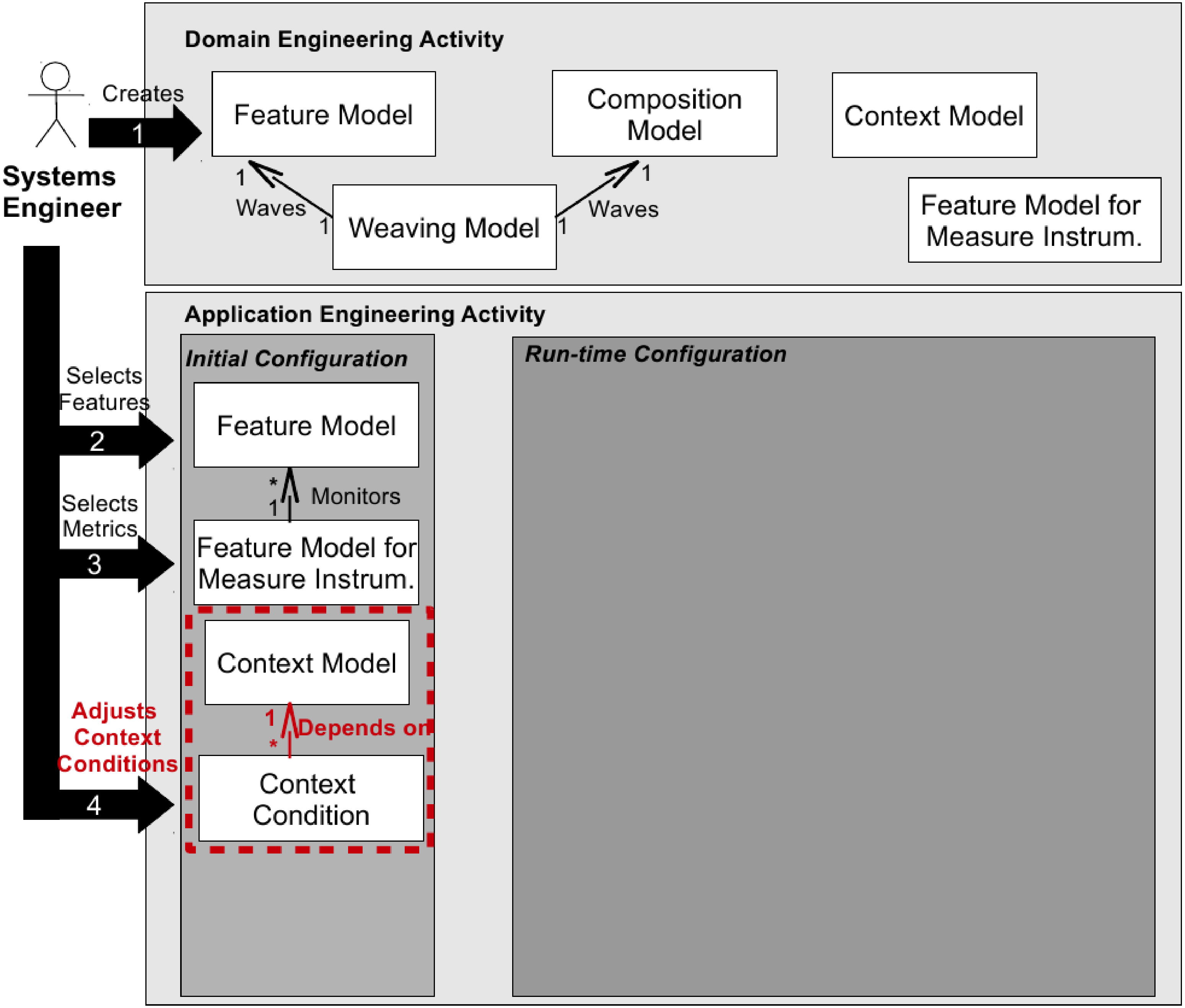


Our Approach

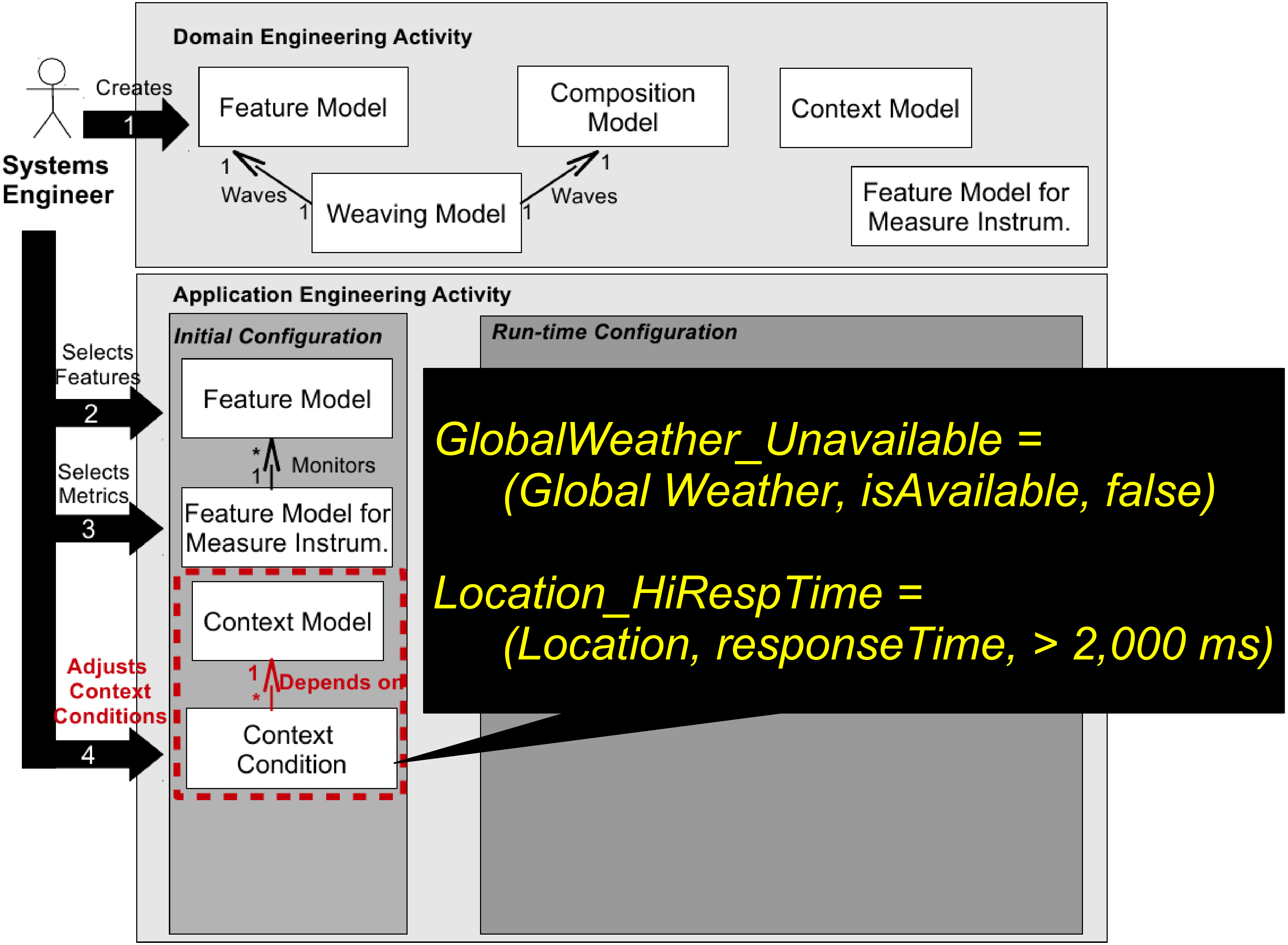


Current Configuration$_{\textit{Measure Instruments}}$ =
{Availability, Response Time, Execution Time}

Our Approach



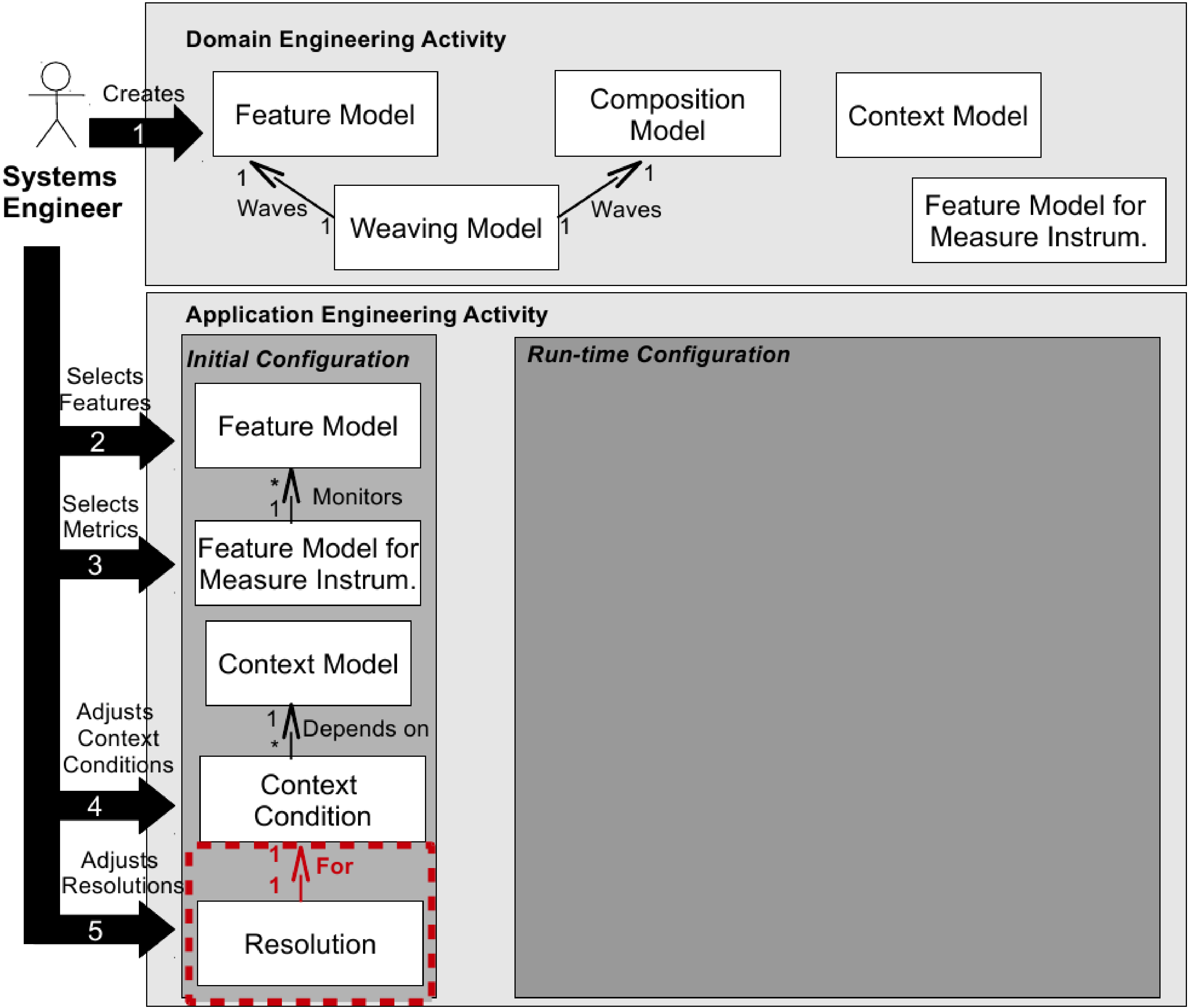
Our Approach



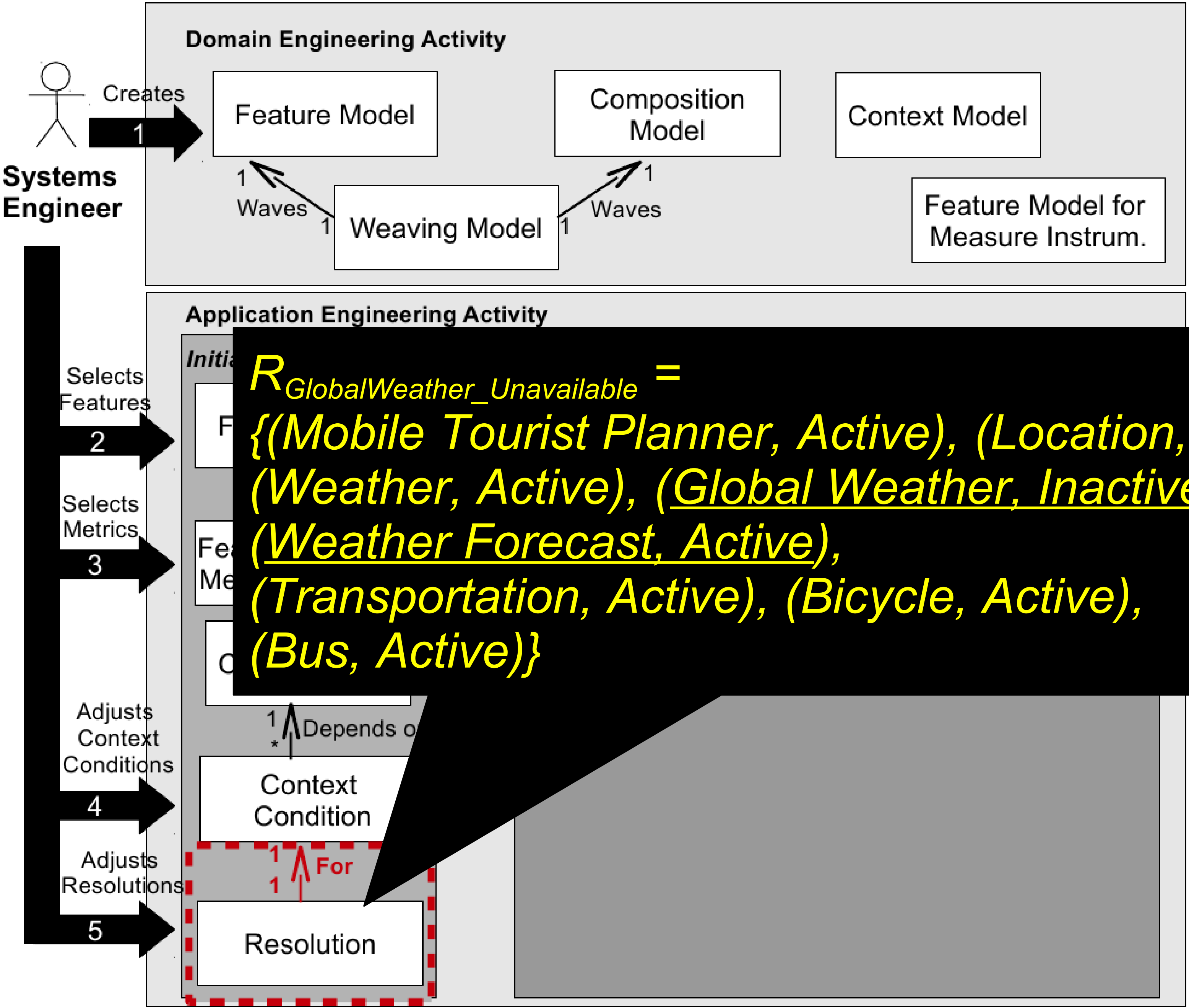
GlobalWeather_Unavailable =
(Global Weather, isAvailable, false)

Location_HiRespTime =
(Location, responseTime, > 2,000 ms)

Our Approach

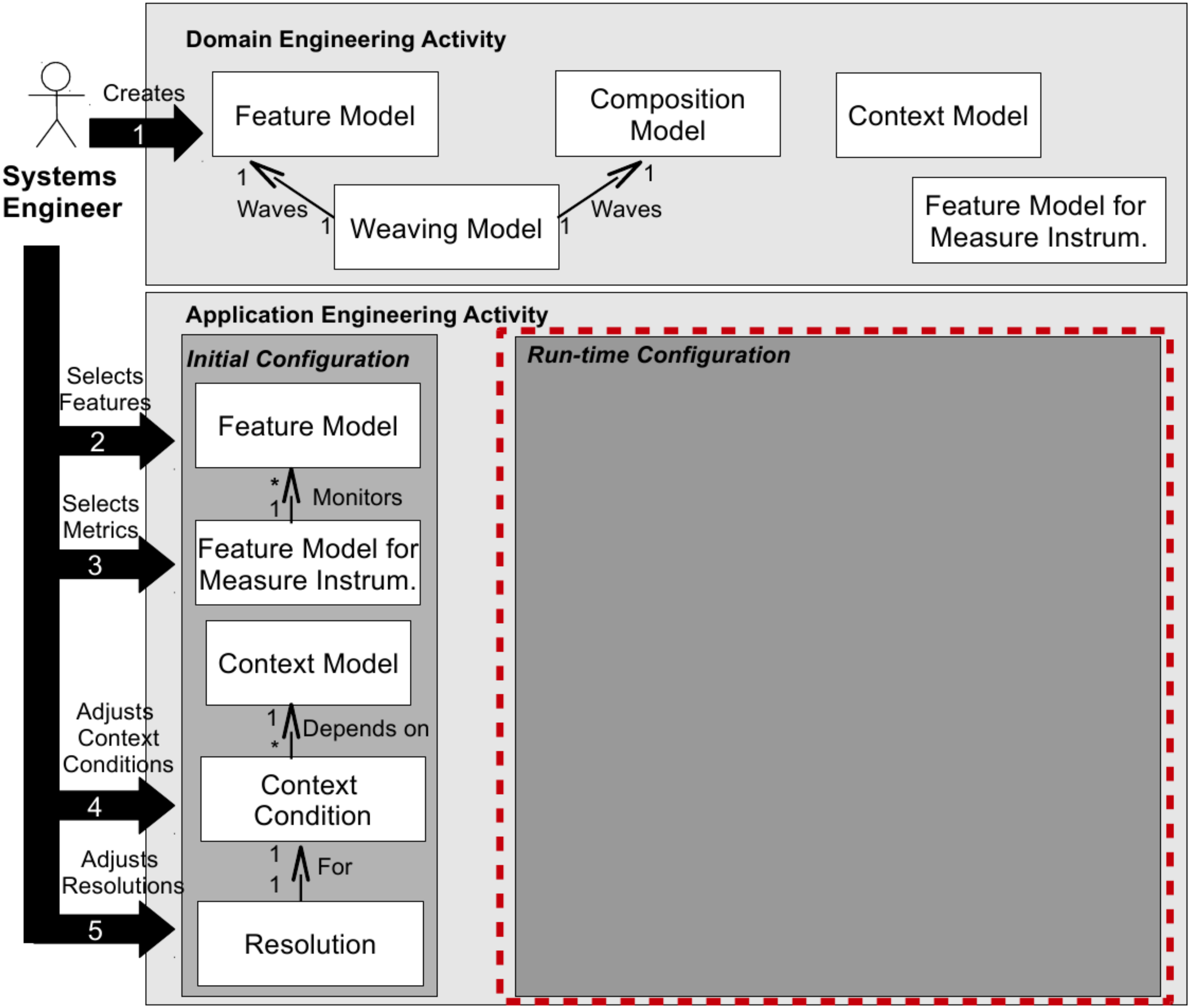


Our Approach



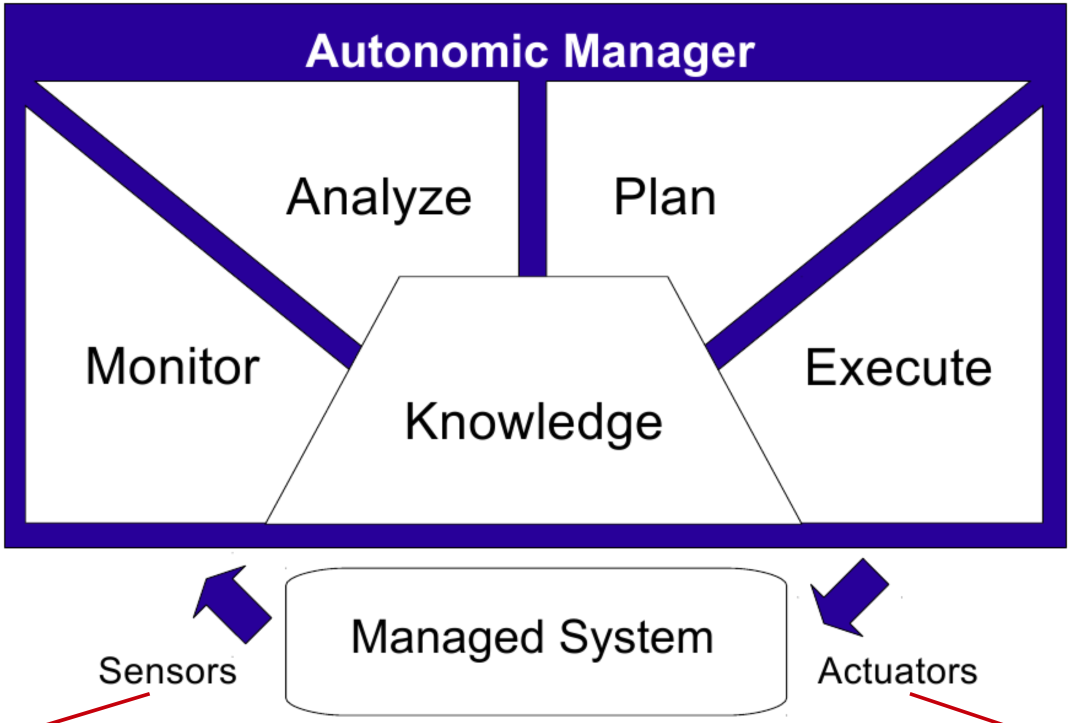
$R_{GlobalWeather\_Unavailable}$ =
{(Mobile Tourist Planner, Active), (Location, Active), (Weather, Active), (Global Weather, Inactive), (Weather Forecast, Active), (Transportation, Active), (Bicycle, Active), (Bus, Active)}

Our Approach



Our Approach

Application Engineering Activity / Runtime Configuration:



Collect information

Service composition

Carry out changes

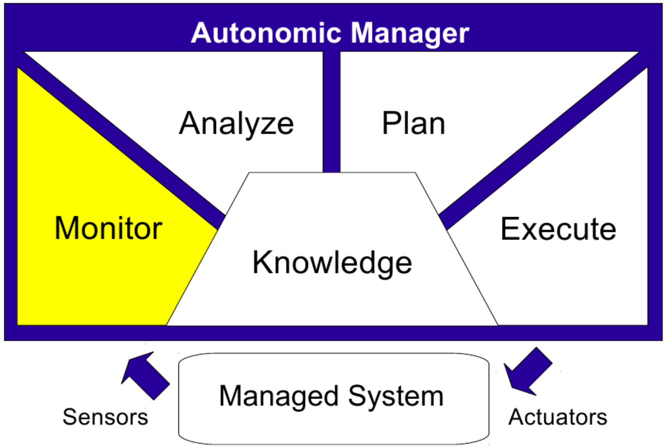
IBM's reference model for autonomic control loops (MAPE-K loop)

Our Approach

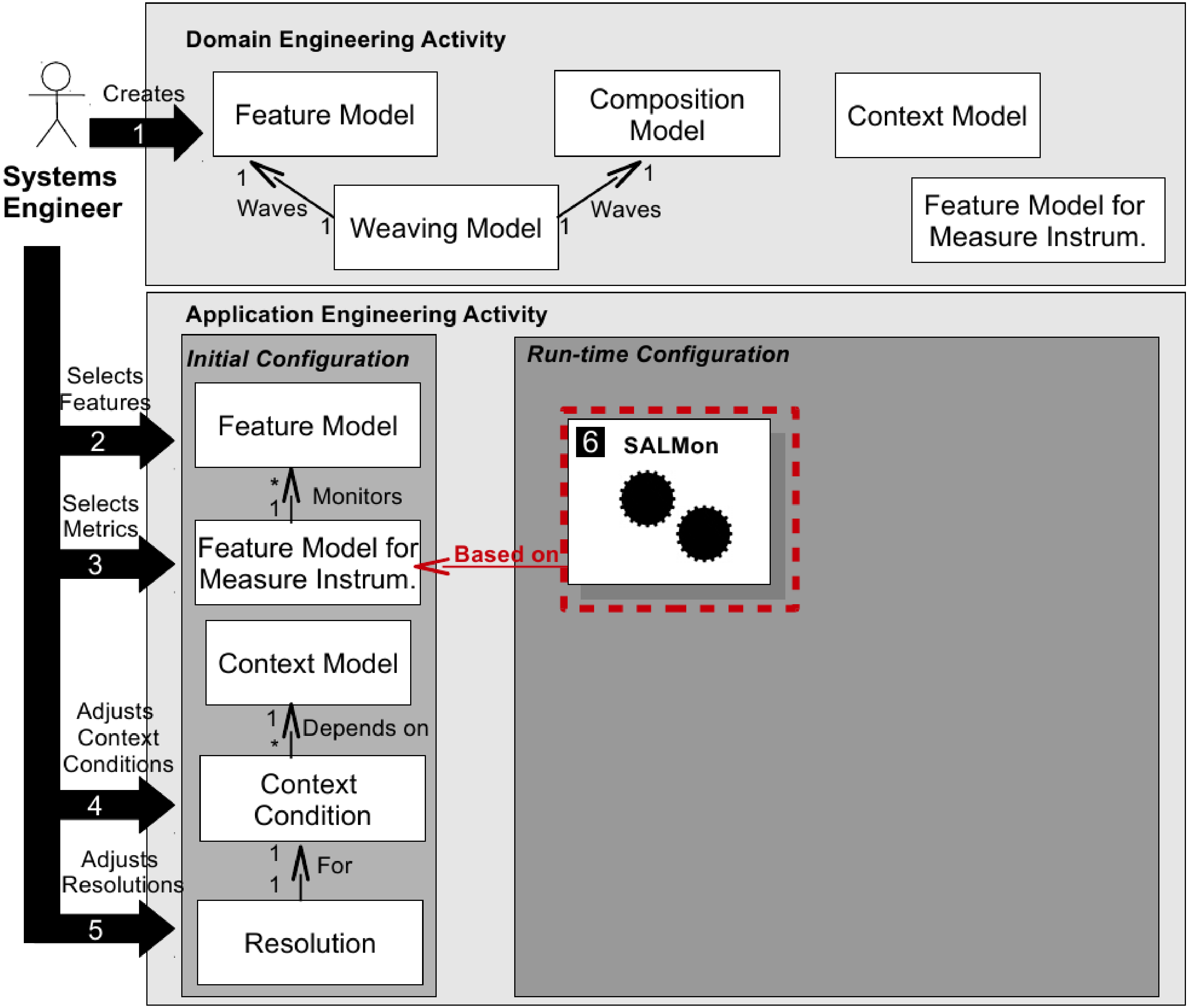
Application Engineering Activity / Runtime Configuration:

a. Monitor:

- Captures **basic metrics** of specific **quality attributes** from the **context**.
- **Monitor component** of **SALMon** (Ameller and Franch @ ICCBSS 2008).



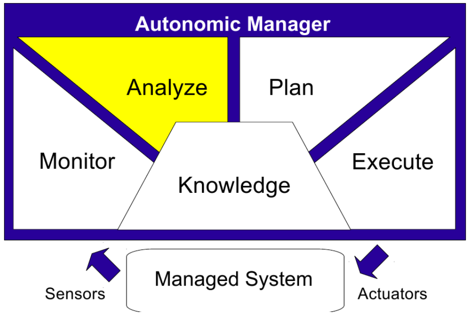
Our Approach

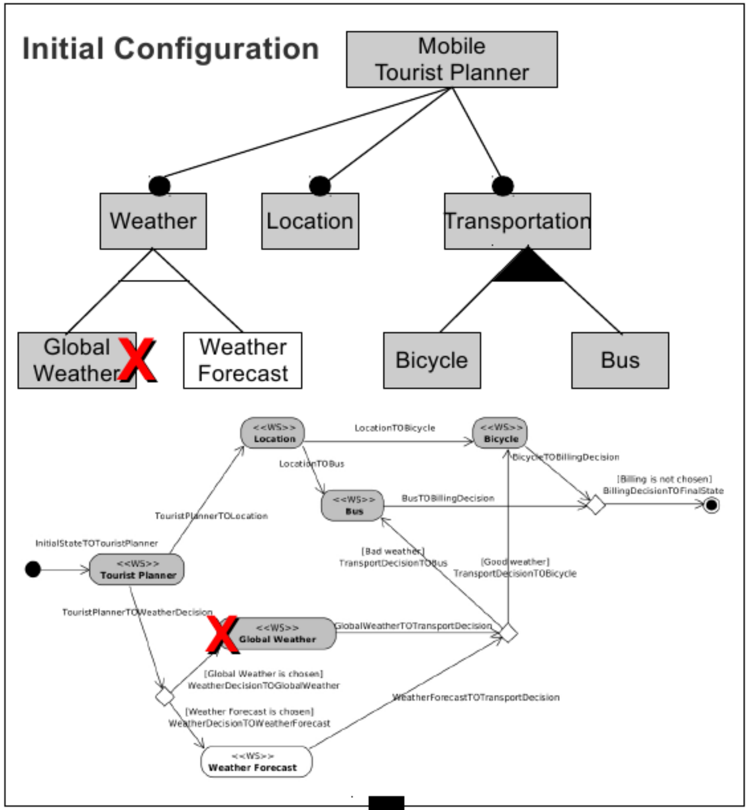


Our Approach

Application Engineering Activity / Runtime Configuration:

b. Analyze:




Initial Configuration
Mobile Tourist Planner
Weather
Location
Transportation
Global Weather
X
Weather Forecast
Bicycle
Bus
<<WS>> Location
LocationTOBicycle
<<WS>> Bicycle
LocationTOBus
BicycleTOBillingDecision
[Billing is not chosen] BillingDecisionTOFinalState
<<WS>> Bus
BusTOBillingDecision
TouristPlannerTOLocation
InitialStateTOTouristPlanner
<<WS>> Tourist Planner
[Bad weather] TransportDecisionTOBus
[Good weather] TransportDecisionTOBicycle
TouristPlannerTOWeatherDecision
X
<<WS>> Global Weather
GlobalWeatherTOTransportDecision
[Global Weather is chosen] WeatherDecisionTOGlobalWeather
[Weather Forecast is chosen] WeatherDecisionTOWeatherForecast
WeatherForecastTOTransportDecision
<<WS>> Weather Forecast

New context event

Context Condition GlobalWeather_Unavailable

Finds

Resolution for GlobalWeather_Unavailable

(Global Weather, Inactive), (Weather Forecast, Active)

▨ Current Configuration

□ Variation Point

Our Approach

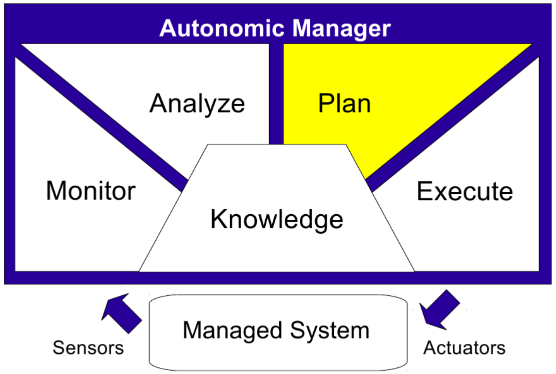
Application Engineering Activity / Runtime Configuration:

c. Plan:

Reconfiguration actions stated as *A∇ and AΔ.*
Given $\boldsymbol{R}_{\textbf{context condition}}$ → ***Reconfiguration Plan.*** $\boldsymbol{R}_{\textbf{globalWeather\_Unavailable}}$**:**

A∇$_{GlobalWeather\_Unavailable}$ = {Global Weather, WeatherDecisionTOGlobalWeather, GlobalWeatherTOTransportDecision}

AΔ$_{GlobalWeather\_Unavailable}$ = {Weather Forecast, WeatherDecisionTOWeatherForecast, WeatherForecastTOTransportDecision}

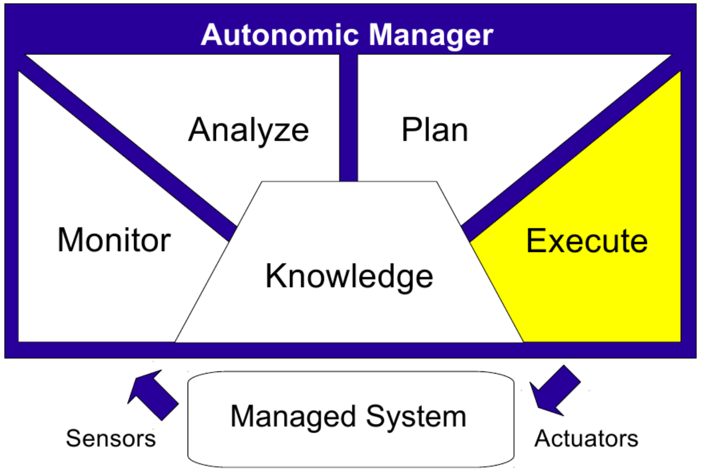


Our Approach

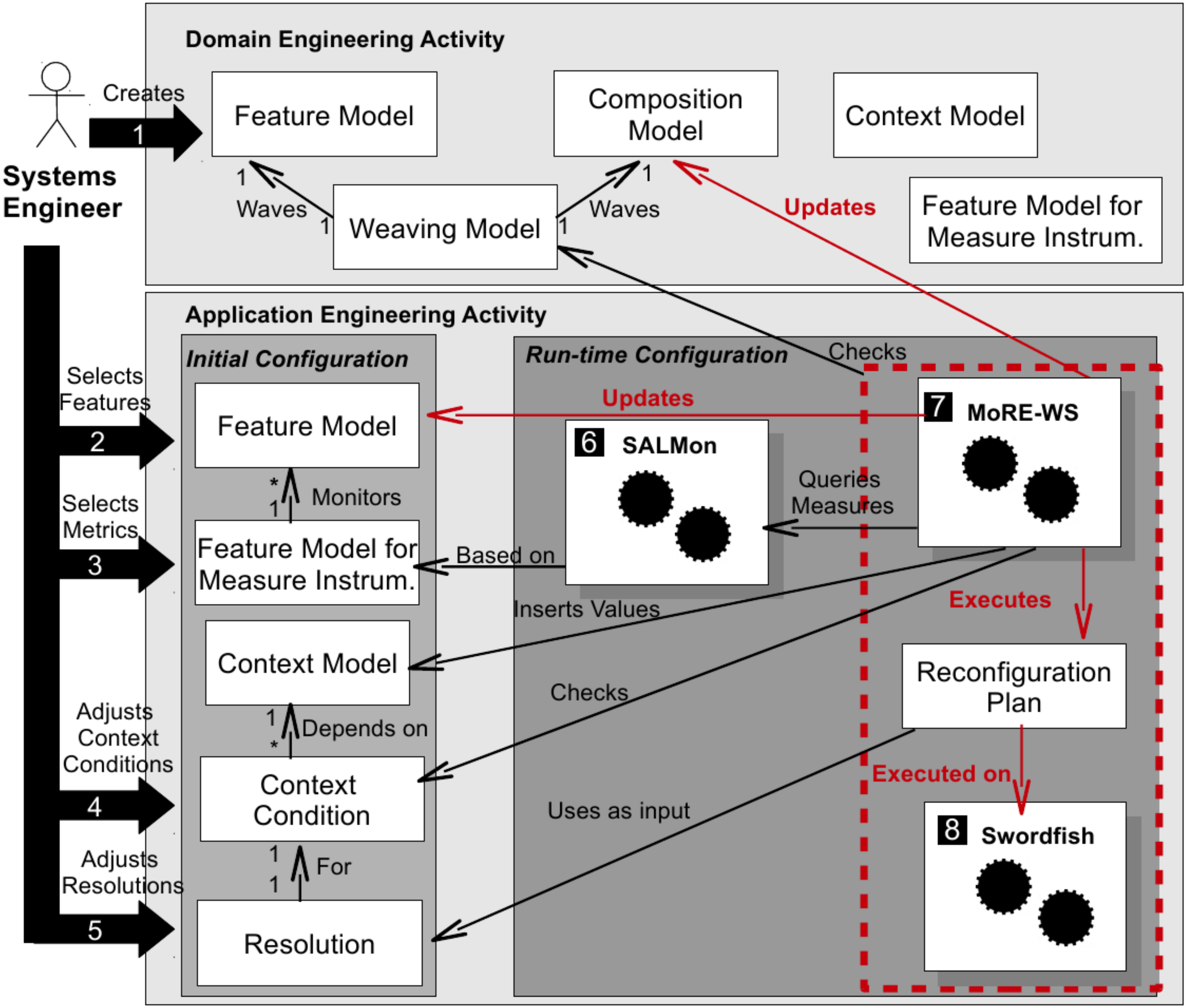
Application Engineering Activity / Runtime Configuration:

d. Execute:

- Execution of the **Reconfiguration Plan**.
- Web services are created using the **Java API for XML Web Services (JAX-WS)** and deployed as **OSGi bundles in Swordfish**.



Our Approach



Our Approach

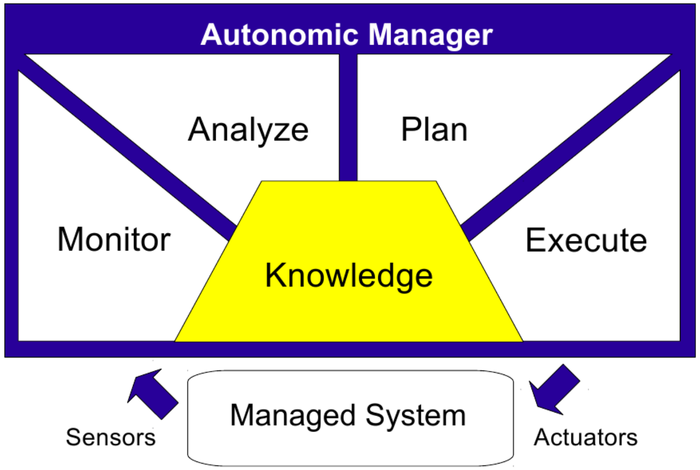
Application Engineering Activity / Runtime Configuration:

e. Knowledge:

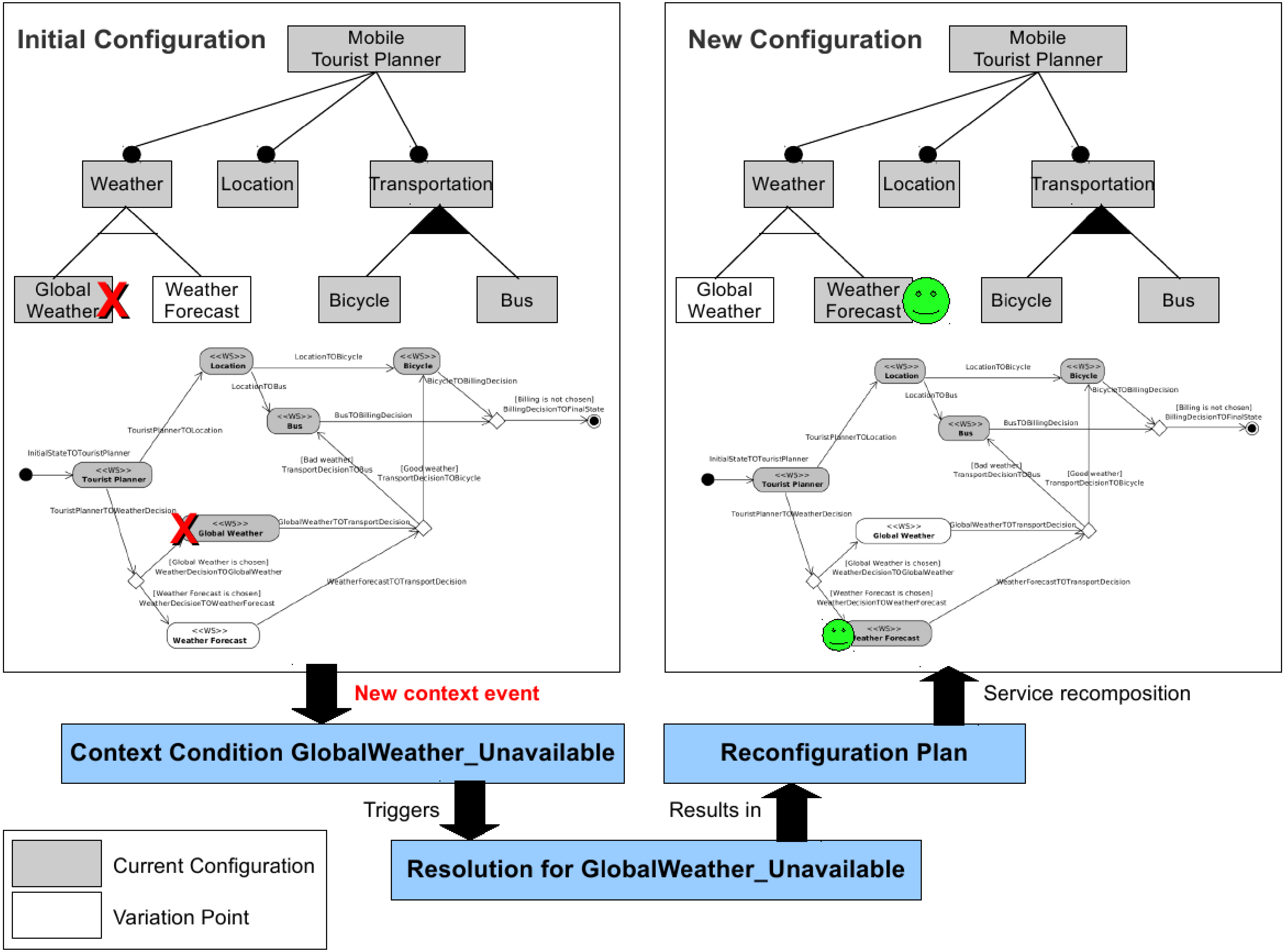
→ **The SPARQL Protocol and RDF Query Language (SPARQL):**

- Data source to be queried: Ontology.
- *INSERT* and *ASK*.

→ **The EMF Model Query framework (EMFMQ):** To query the *Feature Model* and the *Weaving Model*.



Our Approach



Initial Configuration
Mobile Tourist Planner
Weather
Location
Transportation
Global Weather
Weather Forecast
Bicycle
Bus
<<WS>> Location
<<WS>> Bicycle
<<WS>> Bus
<<WS>> Tourist Planner
<<WS>> Global Weather
<<WS>> Weather Forecast
LocationTOBicycle
LocationTOBus
BicycleTOBillingDecision
[Billing is not chosen] BillingDecisionTOFinalState
BusTOBillingDecision
TouristPlannerTOLocation
InitialStateTOTouristPlanner
[Bad weather] TransportDecisionTOBus
[Good weather] TransportDecisionTOBicycle
TouristPlannerTOWeatherDecision
GlobalWeatherTOTransportDecision
[Global Weather is chosen] WeatherDecisionTOGlobalWeather
[Weather Forecast is chosen] WeatherDecisionTOWeatherForecast
WeatherForecastTOTransportDecision
New Configuration
Mobile Tourist Planner
Weather
Location
Transportation
Global Weather
Weather Forecast
Bicycle
Bus
<<WS>> Location
<<WS>> Bicycle
<<WS>> Bus
<<WS>> Tourist Planner
<<WS>> Global Weather
<<WS>> eather Forecast
LocationTOBicycle
LocationTOBus
BicycleTOBillingDecision
[Billing is not chosen] BillingDecisionTOFinalState
BusTOBillingDecision
TouristPlannerTOLocation
InitialStateTOTouristPlanner
[Bad weather] TransportDecisionTOBus
[Good weather] TransportDecisionTOBicycle
TouristPlannerTOWeatherDecision
GlobalWeatherTOTransportDecision
[Global Weather is chosen] WeatherDecisionTOGlobalWeather
[Weather Forecast is chosen] WeatherDecisionTOWeatherForecast
WeatherForecastTOTransportDecision
New context event
Service recomposition
Triggers
Results in

Context Condition GlobalWeather_Unavailable

Reconfiguration Plan

Resolution for GlobalWeather_Unavailable

▨	Current Configuration
□	Variation Point

Conclusions

- Presented a method to design and implement context-aware autonomous Web services in system families.
- Autonomic Computing, SPL engineering, DSPL architecture, and models at runtime.
- Small case study using MoRE-WS prototype.

Future Work

Evaluate our approach with respect to:

- **Autonomic-level achievement**.
- **Scalability** of **model-handling** technologies at runtime.

Tool to **validate reconfigurations** of service compositions at **design time** to **prevent negative effects** during **execution**.

Thanks!

Questions?

harveyalferez@um.edu.mx