Multiagent Systems Design (MASD)

# 3. Agent-Oriented Methodologies
## Part 2: The PROMETHEUS methodology.

Javier Vázquez-Salceda
MASD

Knowledge Engineering and Machine Learning Group
UNIVERSITAT POLITÈCNICA DE CATALUNYA
https://kemlg.upc.edu



## Methodological Extensions to Object-Oriented Approaches

- A means for agent technologies to gain traction within industrial settings may be by being introduced through well-established technologies
- The Unified Modeling Language (UML) has gained wide acceptance for the representation of engineering artifacts using the object-oriented paradigm
- There are several attempts to extend UML so as to encompass agent concepts
- In general, building methods and tools for agent-oriented software development on top of their object-oriented counterparts seems appropriate
  - It lends itself to smoother migration between these different technology generations
  - It improves accessibility of agent-based methods and tools to the object-oriented developer community which, as of today, prevails in industry.

# The Prometheus Methodology

- **Phases**
- **Tools**
- **From Prometheus to ROADMAP**

Knowledge Engineering and Machine Learning Group
UNIVERSITAT POLITÈCNICA DE CATALUNYA
https://kemlg.upc.edu



## Prometheus

- Prometheus, is an iterative methodology covering the complete software engineering process
  - Analysis, Design, Detailed design, Implementation
- Aims at the development of intelligent agents (in particular BDI agents)
  - Uses goals, beliefs, plans, and events.
- The resulting specification can be implemented in any agent implementation software that covers such abstractions
  - Specially aimed for implementation with JACK
- It is evolved out of practical experiences
- It is aimed at industrial software development, not researchers

## Prometheus Overview

- Methodology developed over 7-8 years in collaboration with industry partner (**Agent Software**). Feedback from many students and industry partner clients.
- Focus on detailed guidance and structure to facilitate tool support.
- Mixture of
  - graphical notation for overview
  - (structured) text notation for detail.
- Hierarchical and modular.
- Prototype tool available and used externally

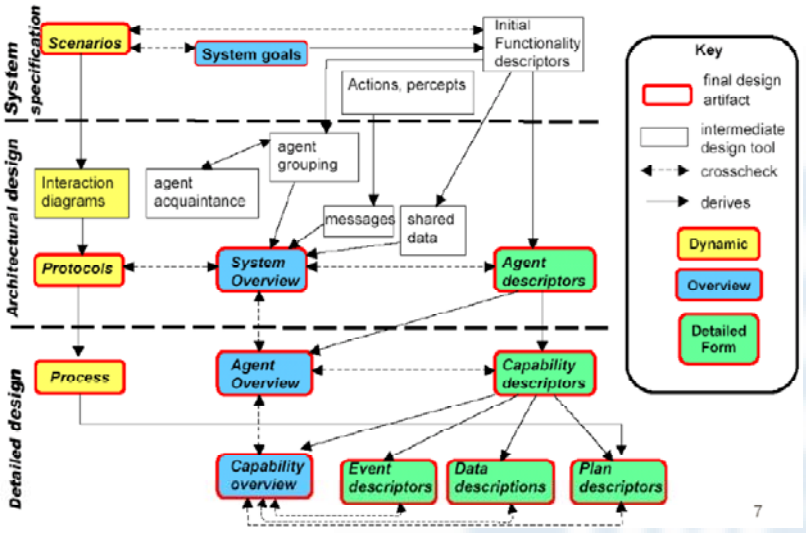




## Prometheus
### Phases

- The Prometheus methodology covers three phases
  - The **system specification** focuses on identifying the basic functions of the system, along with inputs (percepts), outputs (actions) and their processing (for example, how percepts are to be handled and any important shared data sources to model the system's interaction with respect to its changing and dynamic environment)
  - The **architectural design phase** subsequent to system specification determines which agents the system will contain and how they will interact
  - The **detailed design phase** describes the internals of each agent and the way in which it will achieve its tasks within the overall system. The focus is on defining capabilities (modules within the agent), internal events, plans and detailed data structures.

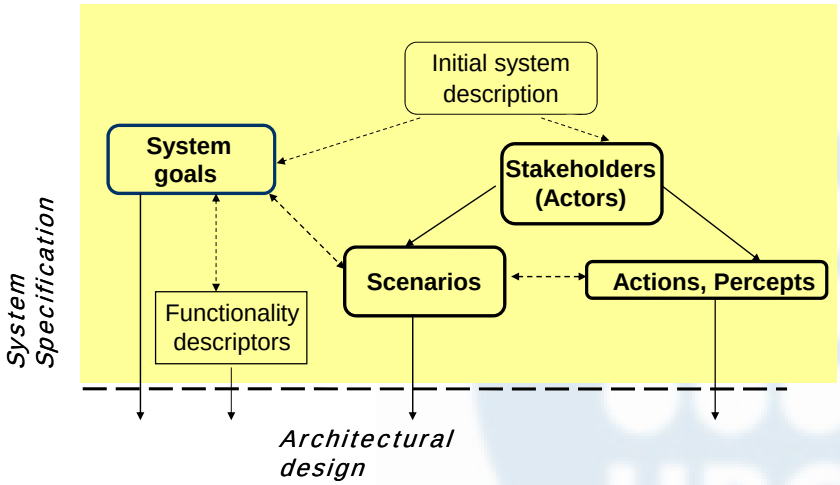
# Prometheus
## Process Overview








# Prometheus
## System Specification Phase



## Prometheus
### System Specification phase

- System defined by
  - Goals: *goal diagram*
  - Scenarios: *user case scenarios*
  - Functionalities: *functionality descriptors*
- System interface with environment described in terms of
  - actions,
  - percepts
  - external data





## Prometheus
### System Specification phase: Steps (non-sequential!)

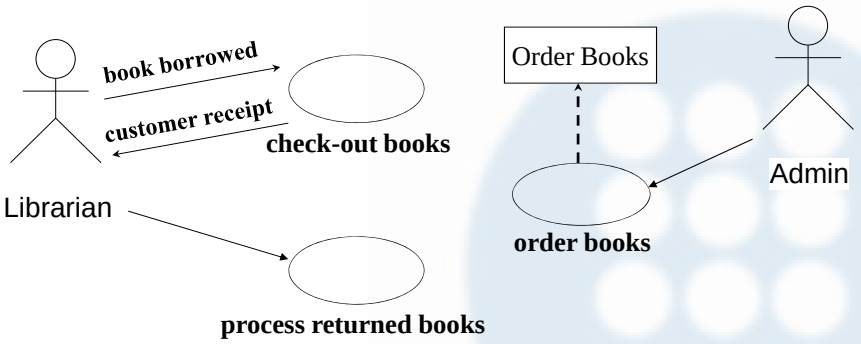
- Start with high-level description of the system (textual)
- Identify actors
- Identify top-level scenarios for each actor
- Identify inputs/outputs (actions/percepts)

> The online bookstore's percepts and events include customers visiting the website, selecting items, placing orders using forms, and receiving email from customers, delivery services and book suppliers. Actions include bank transactions, sending email, and placing delivery orders.

# Prometheus

## System Specification phase: Steps (non-sequential!)

- Add a corresponding system goal for each use-case



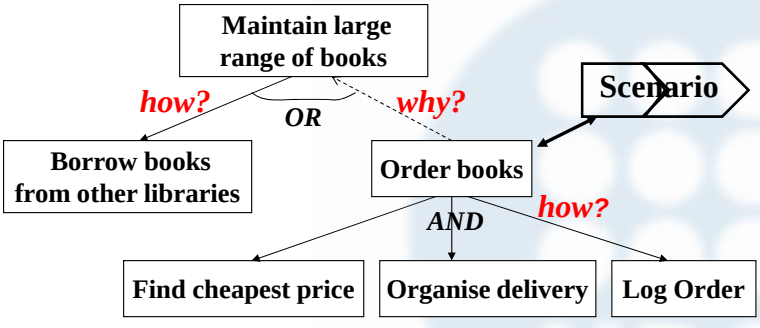





# Prometheus

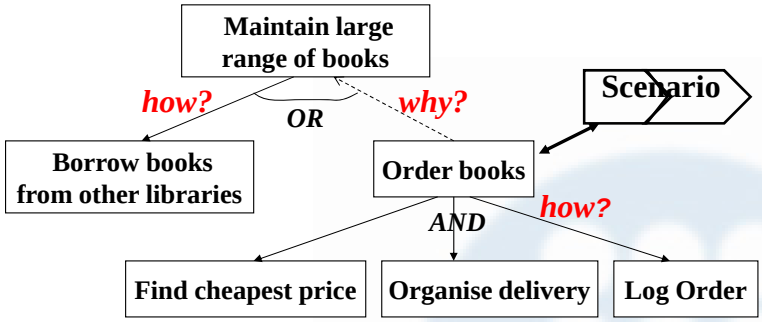
## System Specification phase: Goal Overview Diagram

- Apply Goal Abstraction to system goals
- Refine Goal (OR/AND refinement)
- Link goals to (sub)scenarios



# Prometheus

## System Specification phase: Goal Overview Diagram




- **good practices:**
  **Except in extreme situations, the goal diagram...**
  - **should be a fully-connected graph**
  - **The abstraction level should be balanced in the different branches.**
  - **All (sub)goals should be linked to scenarios**





# Prometheus

## System Specification phase: Steps (non-sequential!)

- Identify the functionalities of the system
  - Idea: identify roles and activities

**NAME: Welcoming**
**Description:** Welcomes a new visitor to the world wide web site (with personalised information if possible).
**Percepts/events/messages:** CustomerArrived (message), CustomerInformation (message)
**Messages sent:** CustomerInformationRequest (message), CustomisedWWWPage (message),
**Actions:** DisplayCustomisedWWWPage
**Data used:** CustomerDB, CustomerOrders
**Interactions:** CustomerManager (via CustomerInformationRequest, CustomerInformation) OnlineInteraction (via CustomisedWWWPage, CustomerArrived)

# Prometheus

## System Specification phase: Steps (non-sequential!)

- Develop and refine the Scenarios and sub-scenarios
  - Steps inside a scenario consist of:
    - Incoming event/percept (→ receiving functionality)
    - Message (sender → receiver)
    - Activity or actions (→functionalities)

**Scenario:** Book Order
**Overview:** The user orders a book. Delivery options are explored and then confirmed (with an OrderRequest). The books are shipped, stock updated, and the user notified.
**Context:** Assumes the book is in stock.
**Steps:**

1. EVENT BookOrder (→ Online Interaction)
2. DeliveryOptionQuery (Online Interaction → Transport Information)
3. DeliveryOptions (Transport Information → Online Interaction) Data read: Transport DB
4. Obtain preferred delivery option (Online Interaction)
5. MakePayment (Online Interaction → Sales Transaction)
6. ACTION BankTransaction (Sales Transaction)
7. PlaceOrder (Sales Transaction → Order Handling)
8. Register order (Order Handling) Writes data: CustomerOrders
9. ACTION EmailCourierCompany (Order Handling)
10. DecreaseStock (Order Handling → Stock Manager)

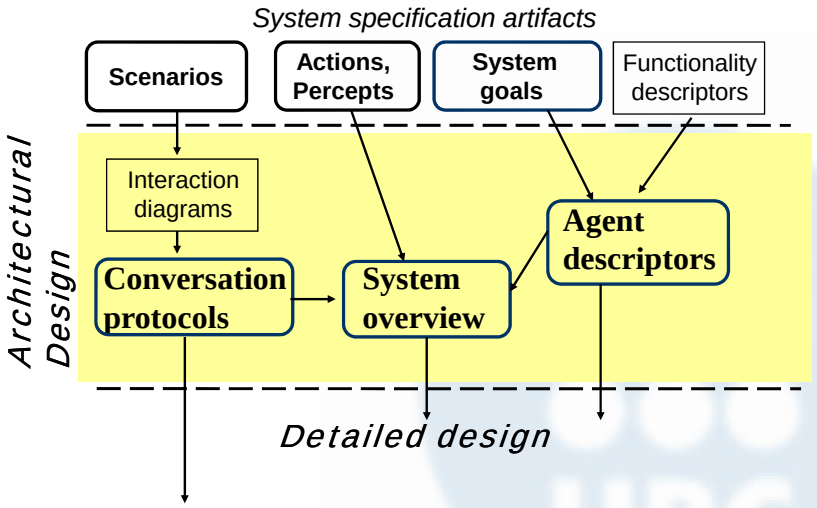
**Variations:** steps 9 (email courier) and 10 (decrease stock) replaced with notification of delay (Order Handling to Customer Contact) and then placing an order for more stock (Order Handling to Stock Manager).





# Prometheus

## Architectural Design Phase



# Prometheus

## Architectural Design Phase: Agent types

- Option 1: The domain already identifies agent types
- Option 2: Identify the **agent types** in the system by
  - Grouping functionalities to agent types based on cohesion and coupling
  - Grouping functionalities that are
    - related based on common sense
    - group functionalities that require a lot of the same information:
      - *Data Coupling Diagram*

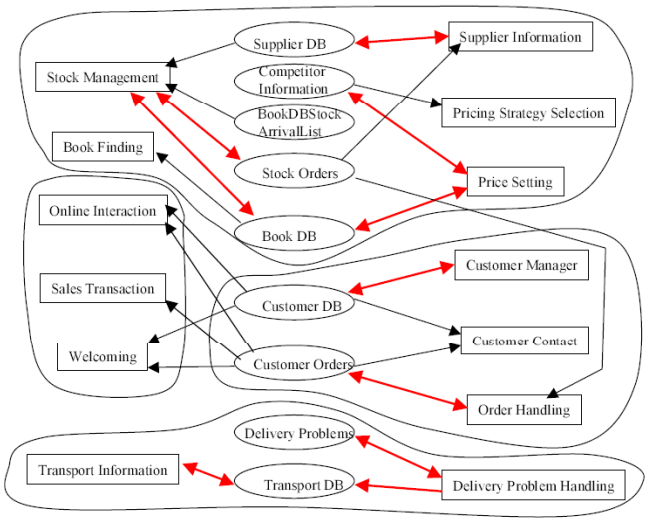
  - Do not group functionalities that are
    - clearly unrelated
    - exist on different hardware platform
    - security and privacy
    - Modifiable by different people
  - Evaluate grouping:
    - Simple descriptive names (heuristic)
    - Generate agent acquaintance diagram





# Prometheus

## Architectural Design Phase: Data Coupling Diagram



# Prometheus

## Architectural Design Phase: Agent Descriptors

- Generate Agent Descriptors based on the agent types
  - How many agents of a each agent type (one, many, dynamic)?
  - What is the life time of the agent?
  - What is the initial state of the agent?
  - What should be done when agent is killed?
  - What is the data used/produced by the agent?
  - To which event the agent should react?





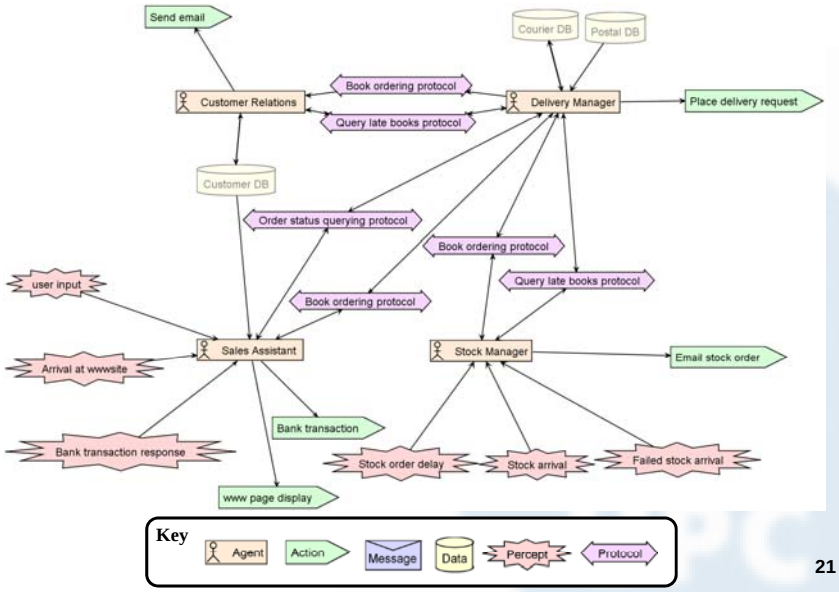
# Prometheus

## Architectural Design Phase: Agent Descriptors

**Name:** Sales Assistant agent
**Description:** greets customer, follows through site, assists with finding books
**Cardinality:** one/customer.
**Lifetime:** Instantiated on customer arrival at site. Demise when customer logs out or after inactivity period.
**Initialisation:** Obtains cookie. Reads Customer DB.
**Demise:** Closes open DB connections.
**Functionalities included:** Online Interaction, Sales Transaction, Welcomer, Book Finder.
**Uses data:** Customer DB, Customer Orders, Book DB.
**Produces data:** Customer preferences, orders, queries
**Goals:** Welcome customer; Update customer details; Respond to queries; Facilitate purchases;
**Events responded to:** new arrival; customer query; customer purchase; credit check response customer response;
**Actions:** Display information to customer (greetings, book info, info requests, Display customised WWW page, RequestCreditCheck messages
**Interacts with:** Warehouse Manager (book request protocol), Delivery Manager (order protocol, order query protocol), Customer Manager (customer information query protocol, customer information update protocol)

# Prometheus

## Architectural Design Phase: System Overview Diagram







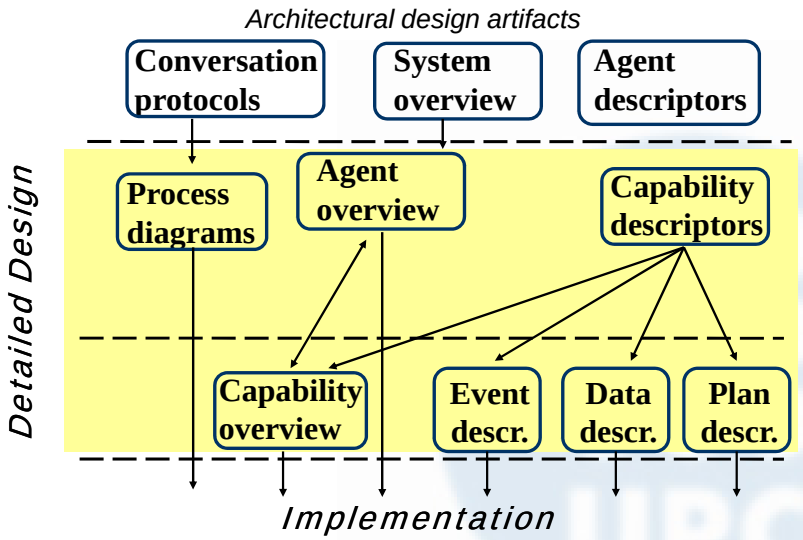

# Design Tip: When agent communication?

- Any protocol interaction should come from some agent communication needs.
- Goals for Agent Communication:
  - Agents able to request (to other ags.) actions or services that they cannot perform by themselves
  - Agents able to ask for information (to other ags.)
  - Agents able to share their beliefs with other ags.
  - Agents able to coordinate with other ags. To solve complex tasks.

- Design Tip:
  - In Prometheus any protocol interaction should be connected to a (sub)goal.

jvazquez@lsi.upc.edu

## Prometheus
### Detailed Design Phase








## Prometheus
### Detailed Design Phase

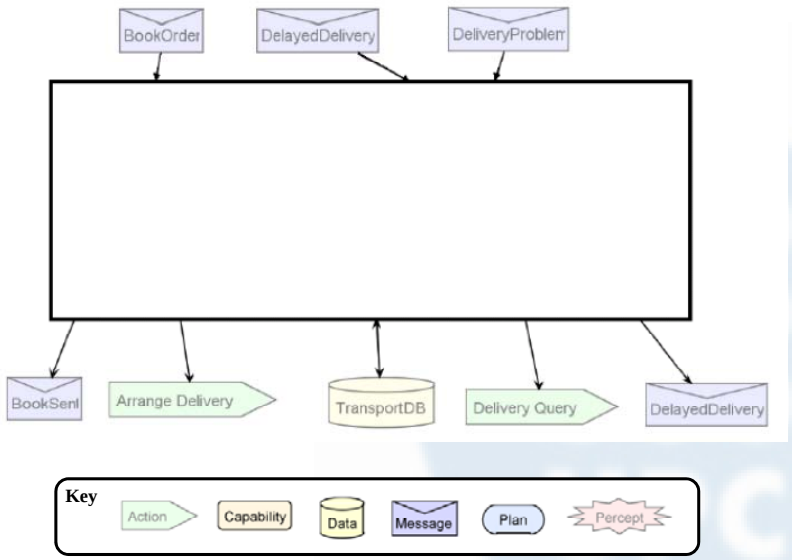
- The details of the agent internals are developed
  - Defined in terms of capabilities, data, events and plans
  - Process diagrams are used as stepping stone between interaction protocols and plans
- Steps (I)
  - Develop the internal structure of individual agents
  - Identify the capability of each agent (start with functionalities)
  - Generate *capability descriptors*

> **Name**: Delivery Problem Handling
> **External interface to the capability:** events used/produced
> **Natural language description:** Respond if books are not in stock
> **Interaction with other capabilities**: Transport capability
> **Data used/produced by the capability:** Note problem to transport capability
> **Inclusion of other capabilities:** None

  - Generate *agent overview diagrams*

# Prometheus

## Detailed Design Phase: Agent Overview Diagrams

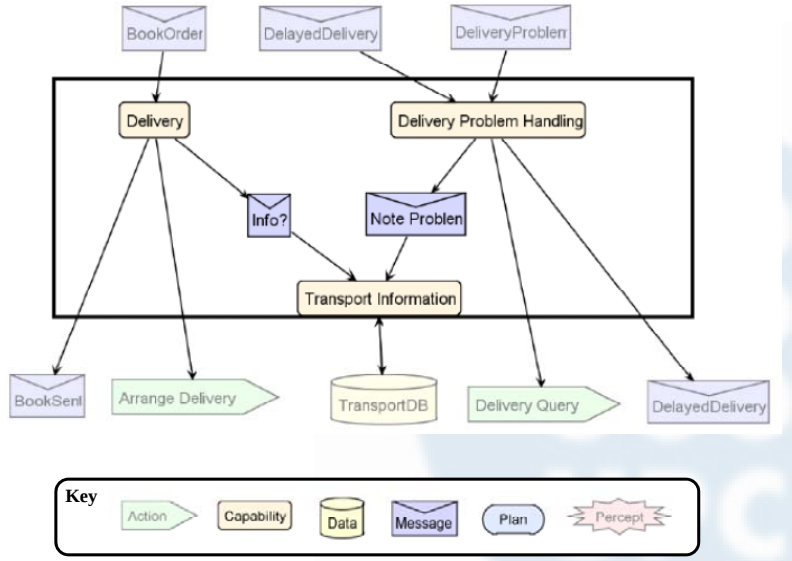







# Prometheus

## Detailed Design Phase: Agent Overview Diagrams



# Prometheus

## Detailed Design Phase: Event, Data & Plan Descriptions

- Steps (II)
  - *Plan descriptions*

| |
|---|
| **Name**: Delivery Problem Handling<br>**Natural language description**: Respond if books are not in stock<br>**Triggering event type**: Delivery problem, Delayed delivery<br>**Plan steps**: Delivery Query, Register problems<br>**Context of performing the plan**: The delivery is delayed<br>**Data used/produced**: Produce note problem |

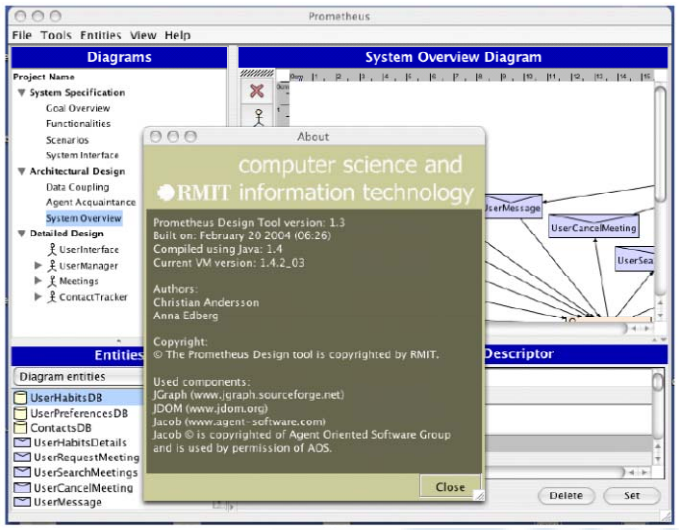
  - *Event descriptions*
    - Identify the purpose of events and the data carried by it
  - *Data descriptions*
    - Identify the data structure and operations on the data





# Prometheus

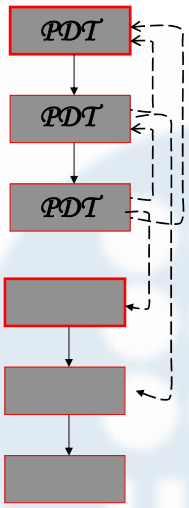
## Tools: the Prometheus Design Tool (PDT)



## Prometheus

Tools: the Prometheus Design Tool (PDT)

- System Specification
- Architectural Design
- Detailed Design
- *Implementation*
- *Debugging*
- *Testing*








## Prometheus: summary

- Main strengths:
  - Structured processes to refine design.
  - Automated consistency checking between (some of) the design artefacts.
  - Hierarchical and modular views.
- Actively continuing development…

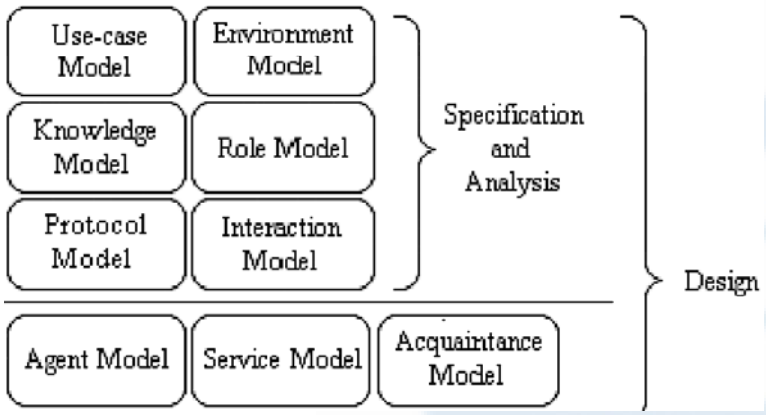
## ROADMAP

- It is an evolution on Gaia v2 with some ideas coming from Prometheus and other methodologies
- Main characteristics:
  - More abstract and high level than Prometheus.
  - Concerned with high level view of models needed.
  - Adds elements to deal with requirements analysis in more detail by using use cases.
  - Aims to better model open systems (Gaia's main limitation)
  - It merges the abstract design and detailed design phases into a single design phase
- There exists only partial tool support:
  - **REBEL (Roadmap Editor Built for Easy Development)** which is designed to help the developer to identify the *Goal Models* and the *Role Models* during the analysis stage.





## ROADMAP
### Overview of Models



# ROADMAP

## Models (I)

- **Use Case Model**: discovers requirements in an effective and sufficient way, by means of scenario identification
  - An important part of the requirement elicitation is made by the identification of the system goals in the *Goal Model*.
- **Environment Model**: derived from the use case model, provides a holistic description of the system environment
- **Knowledge Model**: derived from above, provides a holistic description of the domain knowledge used in the system
- **Role Model** identifies the key roles of the system and usually correspond to individuals, groups or organizations. They are associated to the goals. and are characterized by four attributes: *Responsibilities*, *Permissions*, *Activities* and *Protocols*.





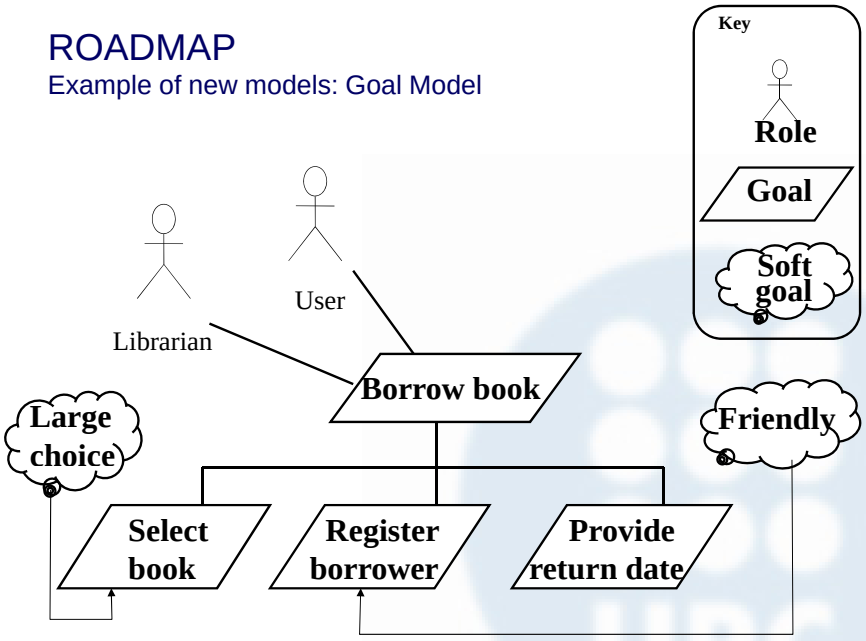
# ROADMAP

## Models

- **Interaction Model** describes the dependencies and relationships between various roles in a multi-agent organization. It is defined by means of AUML interaction diagrams.
  - Further detail of the patterns of interaction is given by the **Protocol Model** at the design phase.
- **Agent Model**: identifies the agent types that make up the system, and can be thought of as a set of agent roles
- **Services Model**: identifies the main services, defining the function of an agent as characterized by input, output, pre-conditions and post-conditions that are required to realize the agent's role
- **Acquaintance Model**: documents the lines of communication between the different agents

# ROADMAP

## Example of new models: Goal Model

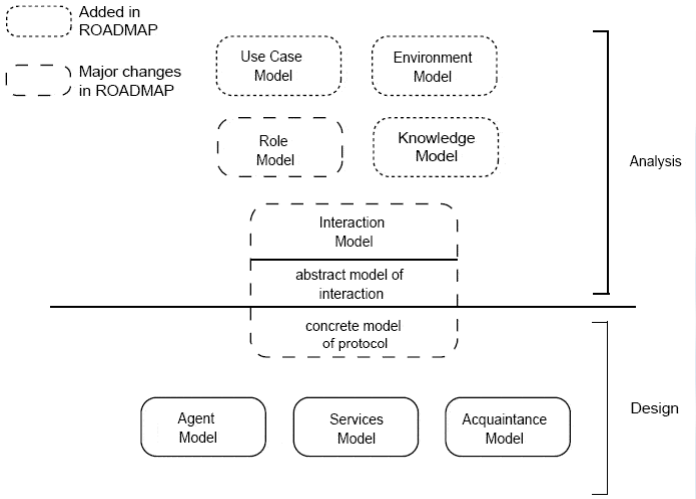






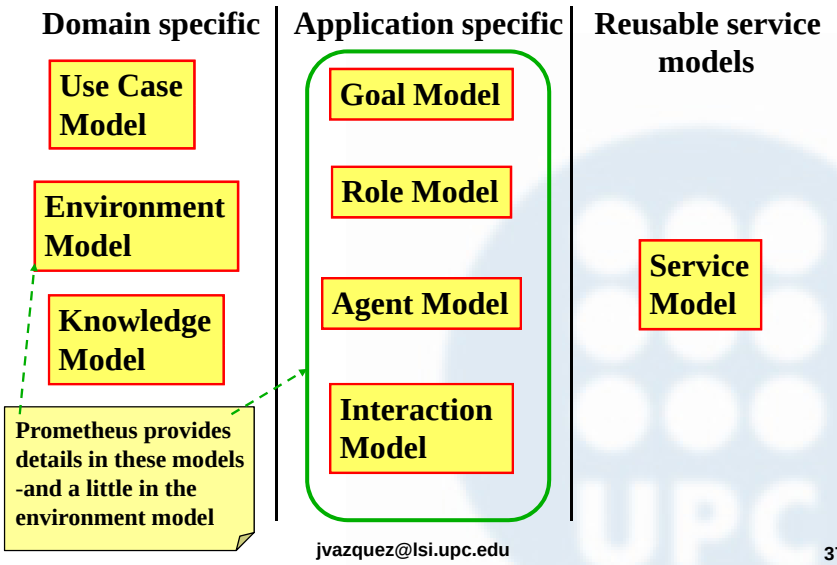

# ROADMAP

## Overview of Models (I): comparison with GAIA



## ROADMAP

Overview of Models (II): comparison with PROMETHEUS








## ROADMAP

Integration with Prometheus

- Since its creation there have been plans to integrate ROADMAP and Prometheus into a single methodology:
  - Prometheus *actors/stakeholders* and *functionalities* become external/internal ***roles***
  - Can identify *goals or scenarios* at top level
  - *Add* ***soft goals*** as annotations on all entities
  - *Percepts and actions* possibly wait till architectural design
- The integration of both methodologies has been first described in 2002...
- ...However, there have been few advances, especially on the tool support.
- Now-a-days, ROADMAP is presented not as a methodology but as an agent-based meta-model.

## References


[1] N.R. Jennings, "On Agent-Based Software Engineering", Artificial Intelligence, 117:227-296, 2000.

[2] F. Zambonelli, N. Jennings, M. Wooldridge, "Organizational Abstractions for the Analysis and Design", 1st International Workshop on Agent-oriented Software Engineering, LNAI No. 1957, 2001.

[3] O. Shehory and A. Sturm, "Evaluation of Modelling Techniques for Agent-Based Systems", Proceedings of The Fifth International Conference on Autonomous Agents, pp. 624-631, 2001.

[4] L. Padgham, M. Winikoff. "Prometheus: A methodology for developing intelligent agents". In Third Int. Workshop on agent-Oriented Software Engineering, July 2002.

[5] L. Padgham, M. Winikoff. "Prometheus: A pragmatic methodology for engineering intelligent agents". In proc. of the OOPSLA 2002 Workshop on Agent-Oriented Methodologies, pg. 97-108, Seatle, 2002.

[6] Juan, T., Sterling, L.: "The ROADMAP Meta-Model for Intelligent Adaptive Multi-Agent Systems in Open Environments". In: Giorgini, P., Müller, J.P., Odell, J.J. (eds.) Agent-Oriented Software Engineering IV. LNCS, vol. 2935, Springer, Heidelberg (2004)


**These slides are based mainly in [2], [4], [5] and material from M. Winikoff, L. Padgham, M. Luck, M. d'Inverno, R. Ashri and M. Dastani**