Multiagent Systems Design (MASD)

3. Agent-Oriented Methodologies
Part 3:
Design tips and good practices

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Multiagent Systems Design (MASD)

Designing a Multiagent System

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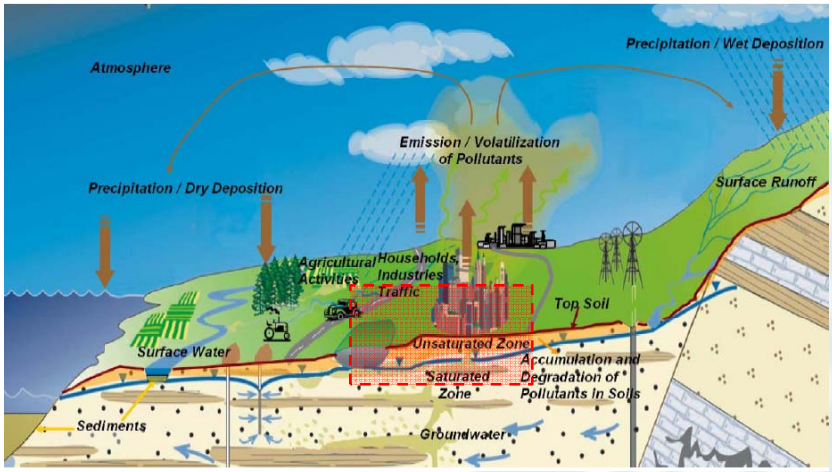
Use case: Distributed River Basin Management



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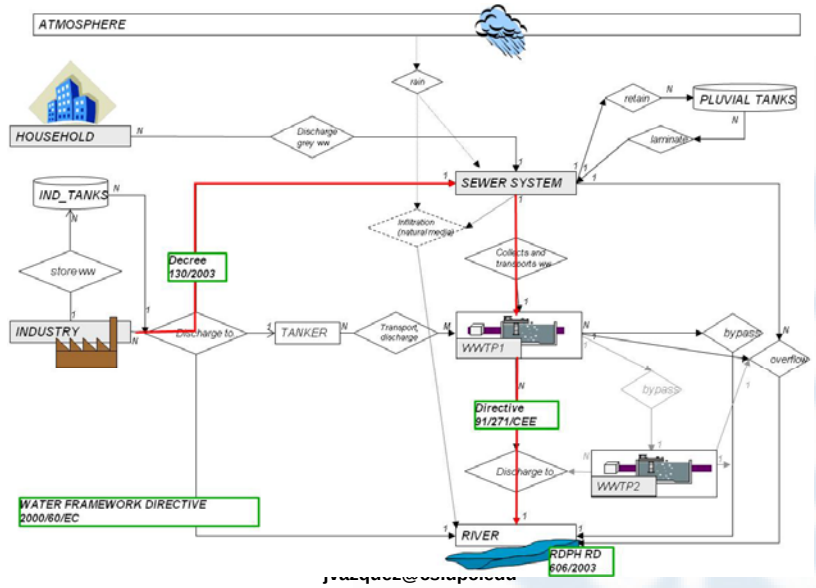
3. Agent-Oriented Methodologies

Use case: Distributed River Basin Management
Process description and regulations



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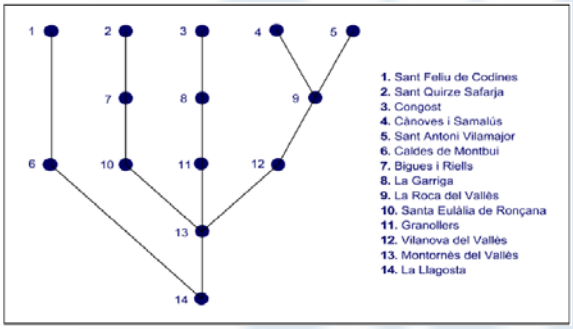
Use case: Distributed River Basin Management
Distributed nature of the problem

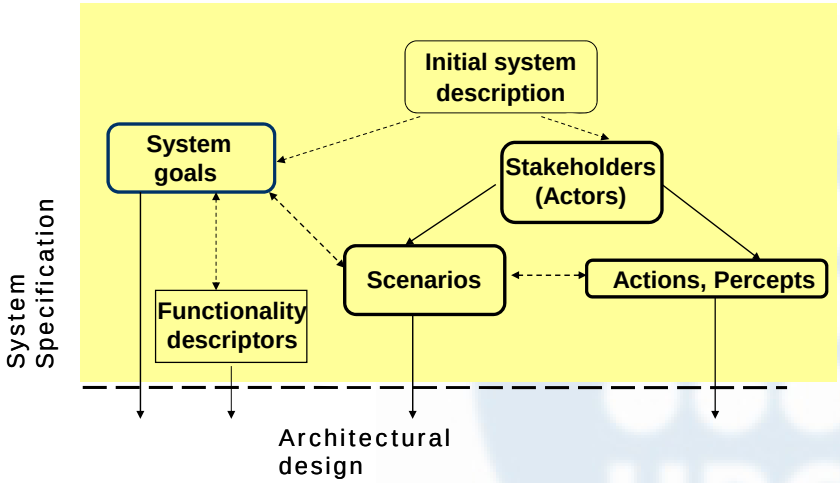
- Idea: to build a MAS to coordinate the operation of the 14 Waste Water Treatment Plants (WWTP) located in the Besos River



Chosen AO Methodology: Prometheus

- 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
System Specification Phase



Prometheus
System Specification phase

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

Note: Most of the MAS design showed in the following slides was made by CAROLINA RUBIO, ATIA CORTÉS and FRANCESC TRAVESA

STAKEHOLDER	PERFORMANCE	ENVIRONMENT	PERCEPTS	ACTIONS
Sewer System	- Drainage and transport of rainfall water, industrial and household ww^2 to the receiving media or to a WWTP - Flood protection	- Sewage transportation - Rain overflows - Pollution episodes	- Detect inflow of rainfall water - Detect inflow of household water	- Temporal storage of rainfall water - Check availability of the WWTPs - Collect and transport water to the pluvial tanks or to the WWTPs
WWTP	- Recycle sludge - Treat ww to be returned to the river according to the Catalan Sanitation Plan	- Urban ww treatment	-Detect quantity of produced ww - Percept the chemical/toxic components of the water	- Collect and transport ww to others WWTPs - Collect and transport water to the river - Check if water treatment is feasible - Apply water treatment - Bypassing water between WWTPs
Industry	- Obey the Catalan Sanitation Plan - Collect polluting wastewater for its processing	- Pollutants transference	- Detect quantity of produced ww	- Collect and transport ww to the sewer system, industrial tanks, TANKER or river - Inform about toxic effluent dumped
River	- Maintenance of an acceptable quantity and quality of the water	- Receiving water	- Percept the chemical/toxic components of the water	- Process quality and quantity data to warn about fraudulent dumps into the river

System Specification phase
Scenarios (1 of 2)

SCENARIO 1	Treat industry's uncontrolled toxic effluent
OVERVIEW	An industry has an uncontrolled toxic effluent and warns authorities
CONTEXT	The toxic concentration in the industrial wastewater is unexpectedly high
STEPS	1. *(Percept)* Detect quantity of produced wastewater 2. *(Action)* Collect and transport ww into industrials tanks 3. *(Action)* Inform about toxic effluent dumped 4. *(Action)* Collect and transport ww into the TANKER 5. *(Action)* Check availability of the WWTPs 6. *(Action)* Collect and transport ww into the suitable WWTP 7. *(Action)* Apply WW treatment
VARIATIONS	*Step 4*. Collect and transport WW to the sewer system

SCENARIO 2	Process a non-notified toxic effluent
OVERVIEW	A wastewater treatment plant detects a non-notified toxic effluent and needs help to process it
CONTEXT	It is not mandatory for the UWS to have a treatment for the toxic effluent
STEPS	1. *(Percept)* Percept the chemical/toxic components of the water 2. *(Action)* Check if water treatment is feasible 3. *(Action)* Bypassing water between WWTPs 4. *(Action)* Apply WW treatment
VARIATIONS	*Step 3*. Apply the primary treatment to the wastewater

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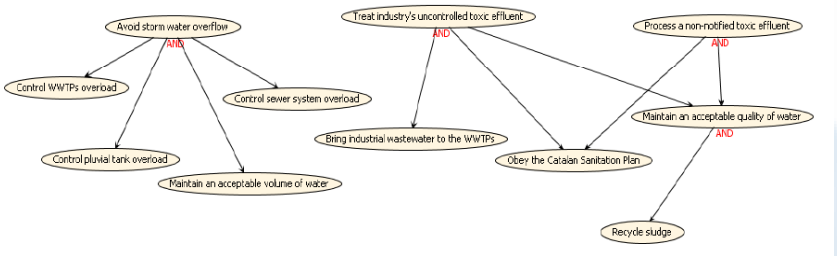
System Specification phase
Scenarios (2 of 2)

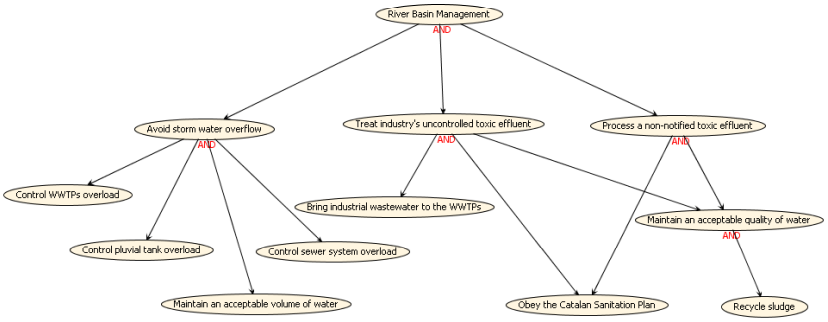
SCENARIO 3	Avoid storm water overflow
OVERVIEW	There is a mild thunderstorm and a waste water treatment plant cannot process all the in-flow alone, and needs to coordinate with others
CONTEXT	The sewer system has only one pipe that collects and transports together the storm water and the different types of wastewater
STEPS	1. *(Percept)* Detect inflow of rainfall water 2. *(Action)* Collect and transport water to the pluvial tanks 3. *(Activity)* Temporal storage of rainfall water 4. *(Action)* Check availability of the WWTPs 5. *(Action)* Bypassing water between WWTPs 6. *(Action)* Collect and transport water to the river
VARIATIONS	*Step 5*. Collect and transport water to the river

System Specification phase
Goal Overview Diagram: first attempt



- **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**

System Specification phase
Goal Overview Diagram: improved



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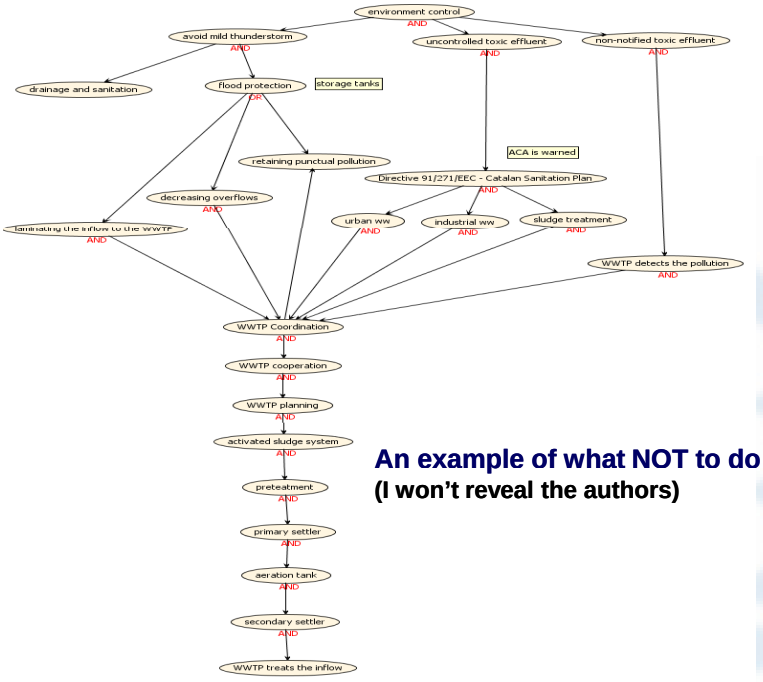
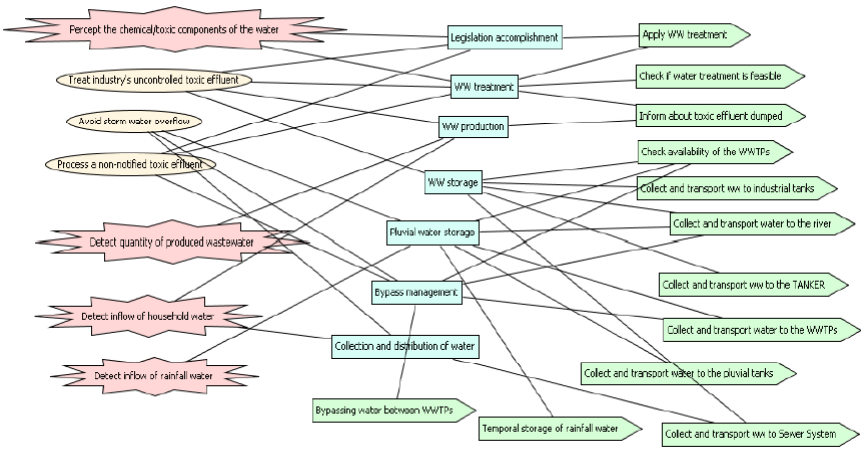


An example of what NOT to do…
(I won't reveal the authors)

System Specification phase
System Roles Diagram



- **A good practice:**
  Keep roles/activities small and specific, so later during design phase you have more flexibility to group them into agents

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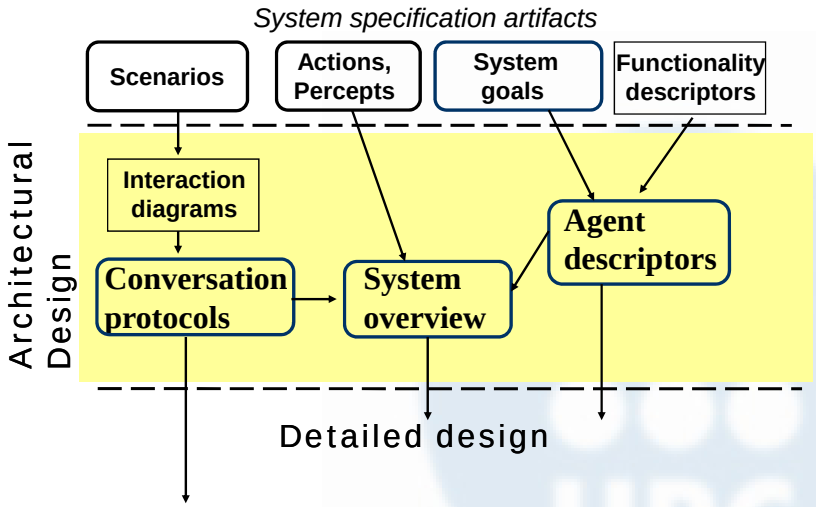
3. Agent-Oriented Methodologies

Prometheus
Architectural Design Phase



Prometheus

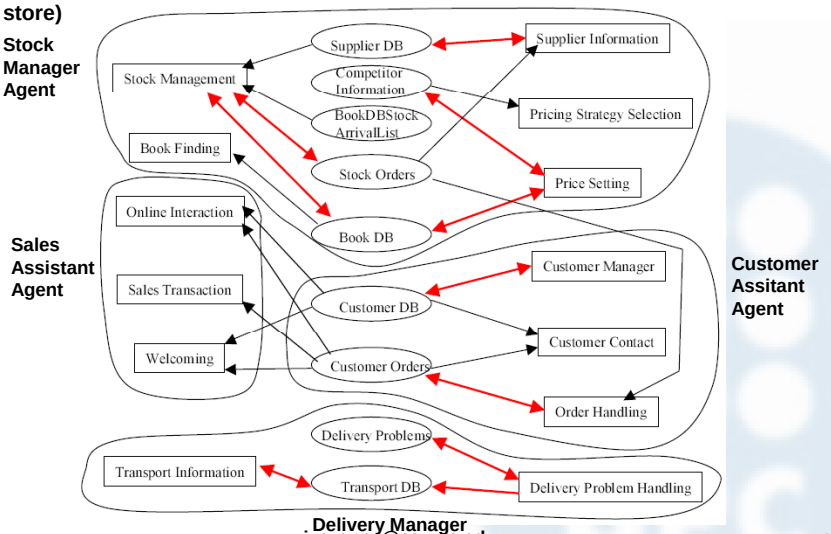
Architectural Design Phase: Identifying Agent types

- option 1: There exists no definition in the environment → we have to identify them
  - Group functionalities to agent types based on cohesion and coupling
  - Group 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
- option 2: The domain already defines the agent types

Identifying agent types

Option 1: The domain does not define stakeholder types/roles

Example from the Prometheus creators (On-line book store)



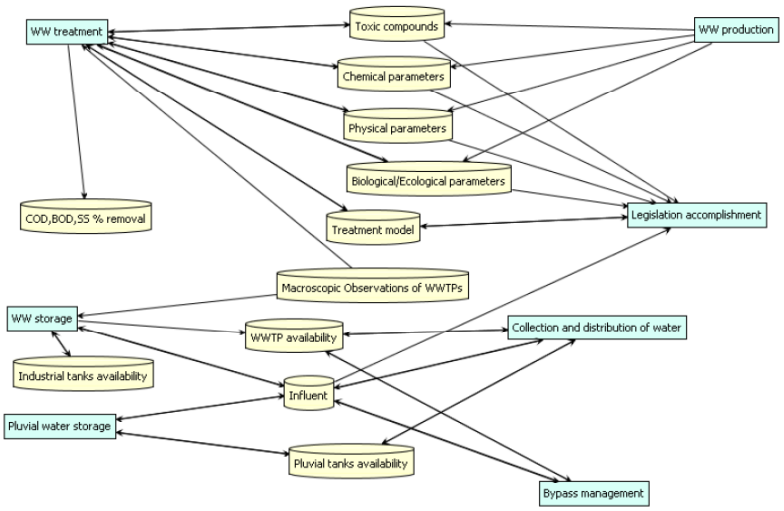
Identifying agent types

Option 1: Example of Agent Descriptor for the on-line Book Store

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)

Identifying agent types

Option 2: These are predefined in the domain



Identifying agent types

Option 2: Example of Agent Descriptor for the Besos River scenario

AGENT	WWTP AGENT
DESCRIPTION	Collection of treatment plants where wastewaters are treated chemically for its sanitation and discharged into the river
CARDINALITY	N (as many treatment plants as the UWS considers)
LIFETIME	Instantiated when in-flow of urban wastewater needs to be discharged for treatment
FUNCTIONALITIES INCLUDED	WW production, Collection and distribution of water, WW treatment, Bypass management
USES DATA	Influent, WWTP availability, Toxic compounds, Chemical parameters, Physical parameters, Biological/Ecological parameters, Treatment model, Macroscopic observation of WWTPs
PRODUCES DATA	Toxic compounds, Chemical parameters, Physical parameters, Biological/Ecological parameters, Influent, WWTP availability, Treatment model, COD BOD SS % removal
GOALS	Maintain an acceptable volume of water, Control WWTPs overload, Obey the Catalan Sanitation Plan, Recycle sludge, Maintain an acceptable quality of water
EVENTS RESPONDED TO	Detect quantity of produced wastewater, Percept the chemical/toxic components of the water
ACTIONS	Apply WW treatment, Check if water treatment is feasible, Check availability of the WWTPs, Collect and transport water to the WWTPs, Collect and transport water to the river, Bypass water between WWTPs
INTERACTS WITH	WWTP Agent (*WWTP availability request protocol*, *WWTP ww transport protocol*), Industry Agent (*Industry tanker ww transport protocol*), Sewer System Agent (*Sewer ww transport protocol*)

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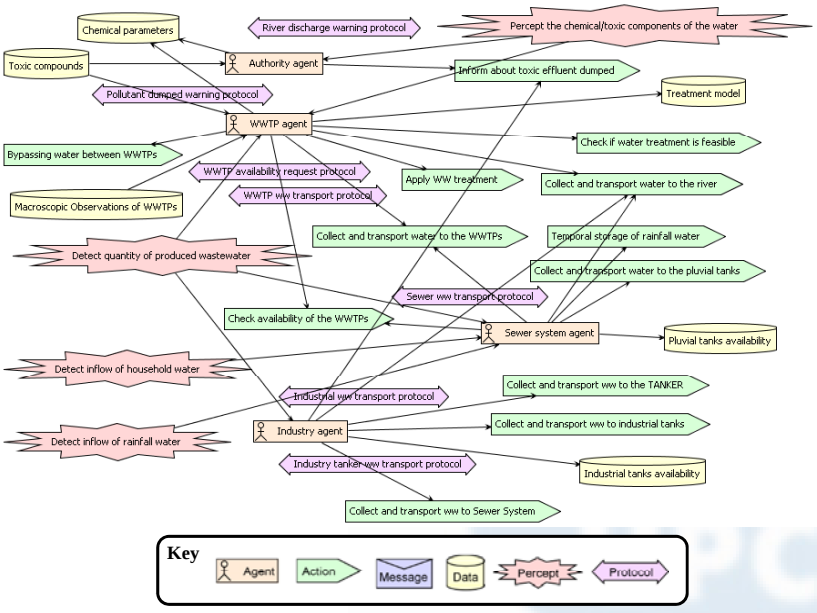
Prometheus

Architectural Design Phase: System Overview Diagram



Design Tip: When agent communication?

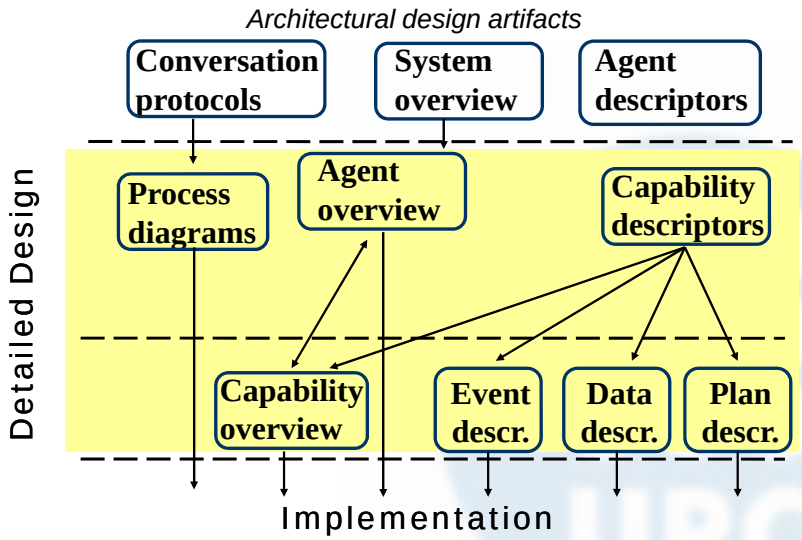
- Any protocol interaction should come from some agent communication needs.
- Goals for Agent Communication:
  - Agents able to request (to other ags.) actions or services that they cannot perform by themselves
  - Agents able to ask for information (to other ags.)
  - Agents able to share their beliefs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

Prometheus
Architectural Design Phase: Protocol description

PROTOCOL	DESCRIPTION	AGENTS INVOLVED
Sewer ww transport	Transports ww from the Sewer system to the nearest WWTP	Sewer System -> WWTP
River discharge warning	Notifies the Authority that the Sewer System discharges ww to the river	Sewer System -> Authority
WWTP ww transport	Sends ww from a WWTP to another	WWTP -> WWTP
WWTP availability request	Requests an available WWTP to treat a toxic effluent	WWTP <-> WWTP Industry -> WWTP Sewer System -> WWTP
Pollutant dumped warning	Industry notifies the discharge of ww	Industry <-> Authority
Industry tanker ww transport	Non-expected ww stored in the industrial tanker transported into the WWTP	Industry -> WWTP
Industrial ww transport	ww coming from industry that pass by the Sewer System before going to the WWTP	Industry -> Sewer System

Prometheus
Detailed Design Phase



Prometheus
Detailed Design Phase

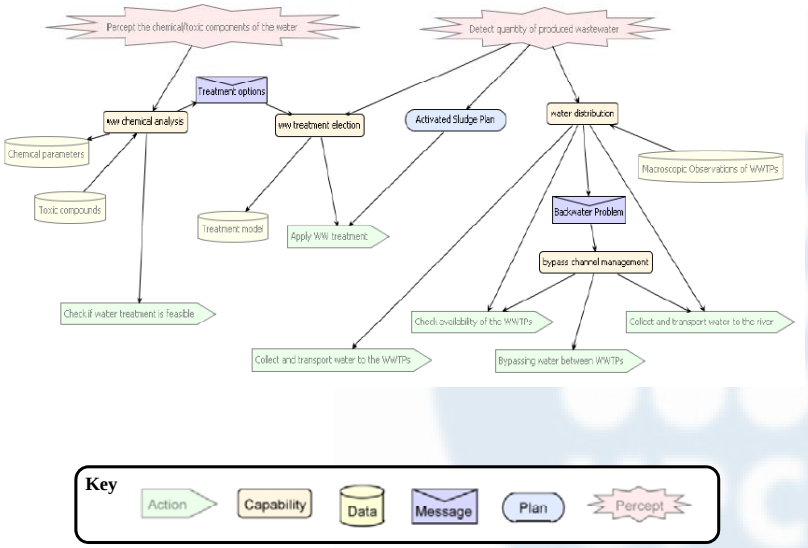
- The details of the agent internals are developed
  - Defined in terms of capabilities, data, events and plans
  - Process diagrams are used as stepping stone between interaction protocols and plans
- Steps (I)
  - Develop the internal structure of individual agents
  - Identify the capability of each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

> **Name**: Bypass channel management
> **External interface to the capability:** events used/produced
> **Natural language description:** Respond if books are not in stock
> **Interaction with other capabilities**: Blackwater problem
> **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 – WWTP Agent



Prometheus

Detailed Design Phase: Event, Data & Plan Descriptions

- Steps (II)
  - *Plan descriptions*

Name: Activated Sludge Plan
Natural language description: Process WW with sludges in tank
Triggering event type: Detected quality of incoming water
Plan steps: Apply WW treatment
Context of performing the plan: normal functioning
Data used/produced: none

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

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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.

These slides are based mainly in [2], [4], [5] and material from previous students of the MASD course