

# The SODA Methodology

Multiagent Systems LS  
Sistemi Multiagente LS

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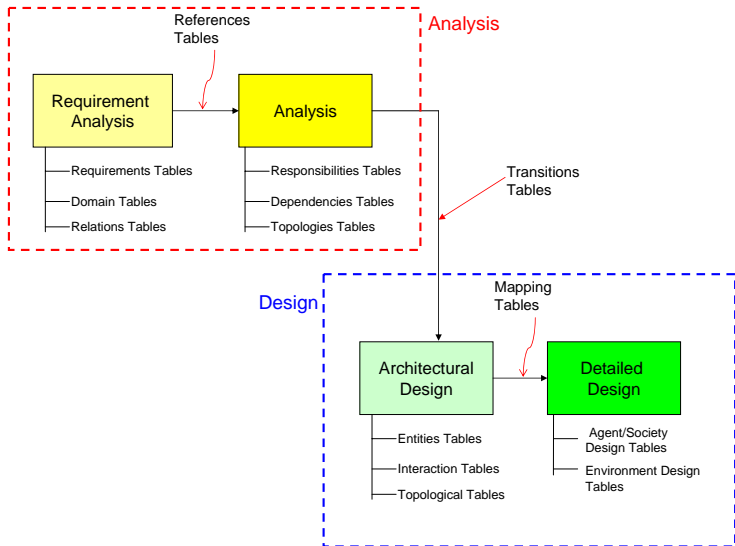
Academic Year 2007/2008

- 1 SODA: Agents and Artifacts Meta-Model and Layering Principle
  - Agents and Artifacts Meta-model
  - Principles and Mechanisms
- 2 The SODA Methodology
  - Analysis Phase
  - Design Phase
  - Web Resources and Conclusions

# Introduction

- SODA (Societies in Open and Distributed Agent spaces) is an agent-oriented methodology for the analysis and design of agent-based systems [Omicini, 2001, Molesini et al., 2005, Nardini et al., 2008]
- SODA focuses on inter-agent issues, like the engineering of societies and environment for MASs
- SODA adopts Agents and Artifacts (**A&A meta-model**) as building blocks for MAS development
- SODA introduces a simple layering principle in order to manage the complexity of the system description
- SODA adopts a tabular representations

# SODA: an overview





# Outline

- 1 SODA: Agents and Artifacts Meta-Model and Layering Principle
  - Agents and Artifacts Meta-model
  - Principles and Mechanisms
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# Artifacts

- Artifacts take the form of objects or tools that agents *share* and *use* to
  - Support their activities
  - Achieve their objectives
- Artifacts are explicitly designed to provide some functions which guide their use
- Example: Coordination Artifacts
  - Govern social activities
  - Enable and mediate agent interaction
  - Mediate the interaction between individual agents and their environment
  - Capture, express and embody the parts of the environment that support agents' activities

# Features

- An artifact exposes
  - **Usage interface**: the set of operations provided by an artifact
  - **Operating instructions**: are a description of the procedure an agent has to follow to meaningfully interact with an artifact over time
  - **Function description**: a description of the functionality provided by the artifact, which agents can use essentially for artifact selection
- Other interesting artifact's features are:
  - *Inspectability*: the state of an artifact, the laws governing its behaviour might be all or partially inspectable by agents
  - *Malleability*: the behaviour of an artifact should be modifiable at execution time in order to adapt to the changing needs or mutable external conditions of a MAS.
  - *Linkability*: artifacts can be used encapsulate and model reusable services in a MAS. To scale up with complexity of an environment, it might be useful to compose artifacts, by allowing artifacts to invoke operations on other artifacts.

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# Classification

- A possible classification
  - **Individual artifacts**: exploited by one agent only in order to mediate its interaction with the environment. In general, individual artifacts are not directly affected by the activity of other agents, but can, through linkability, interact with other artifacts in the MAS;
  - **Social artifacts**: exploited by more than one agent, mediate between two or more agents in a MAS. In general, social artifacts typically provide MASs with a service which is in the first place meant to achieve a social goal of the MAS, rather than an individual agent goal.
  - **Environmental artifacts**: which mediate between a MAS and an external resource. In principle, environmental artifacts can be conceived as a means to raise external MAS resources up to the agent cognitive level.

# Agents & Artifacts

- Artifacts constitute the basic building blocks both for
  - MAS analysis/modelling
  - MAS development
- Agents and Artifacts can be assumed as two fundamental abstractions for modelling MAS structure
  - Agents speaking with other agents
  - Agents using artifacts to achieve their objectives

# Meta-model Ingredients

- Agents & Artifacts lead to new ontological meta-model for MASs
- Artifacts allow to
  - Model the environment as a first-class entity
  - Engineer the space of interaction among agents (not only mere conversations between agents, but complex agent interaction patterns)
  - Enrich MAS design with social/organisational structure, topological models, as well as (complex) security models
- In Particular in SODA [Molesini et al., 2006a]. . .
  - Agents model individual/social activities
  - Artifacts *glue* agents together:
    - They mediate between individual agents and MAS
    - They build up agent societies
    - They wrap up and bring to the cognitive level of agents the resources of MAS

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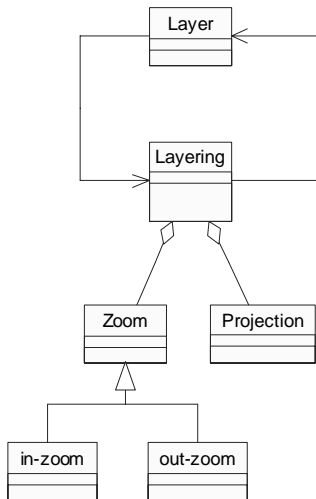
# Layering and MASs

- In many branches of sciences, systems are represented as organised on different layers
- Each level is essential to the general understanding of the system's wholeness, but at the same time, no level can be understood in isolation
- When applied to the engineering of MASs, this principle suggests
  - that MAS models, abstractions, patterns and technologies can be suitably categorised and compared using a layered description
  - that agent-oriented processes and methods should support some forms of MAS layering.

# Layering in SODA: The Meta-Model

[Molesini et al., 2006b, Molesini et al., 2007]

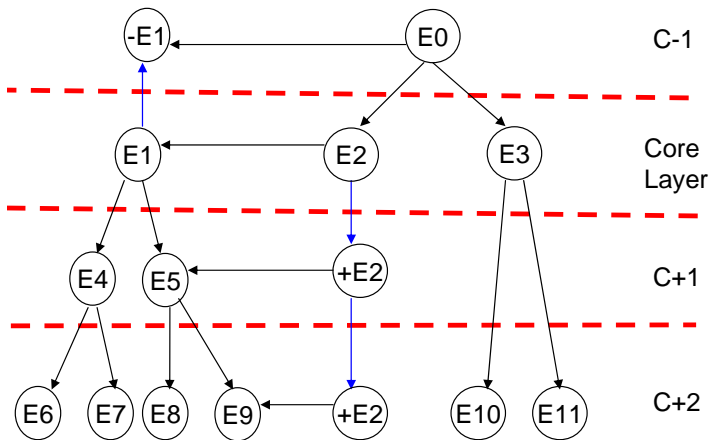
- The layering principle is achieved by means of the **zoom** and **projection** mechanisms.
- Two kinds of zoom
  - *in-zoom*: from abstract to a more detailed layer
  - *out-zoom*: from detailed to a more abstract layer
- The *projection mechanism* projects entities from one to another layer



# Layering Principle

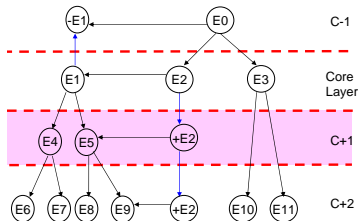
- In general, when working with SODA, we start from a certain layer, we could call *core layer*, and it is labelled with “c”
- The core layer is always **complete**
- In the other layer we find only the in/out zoomed entities and the projection entities.
- The in-zoomed layers are labelled with “c+1”, “c+2” and the out-zoomed layers are labelled “c-1”, “c-2”...
- The projection entities will be labelled with “+” if the projection is from abstract layer to detailed layer, “-” otherwise
- The only relations between layers are the *zooming relation* express by means of zooming table (in the following)
- If we have relation between entities belonging different layers we have to project these entities in the same layer

# Example

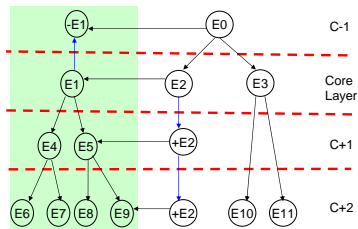


# System's views

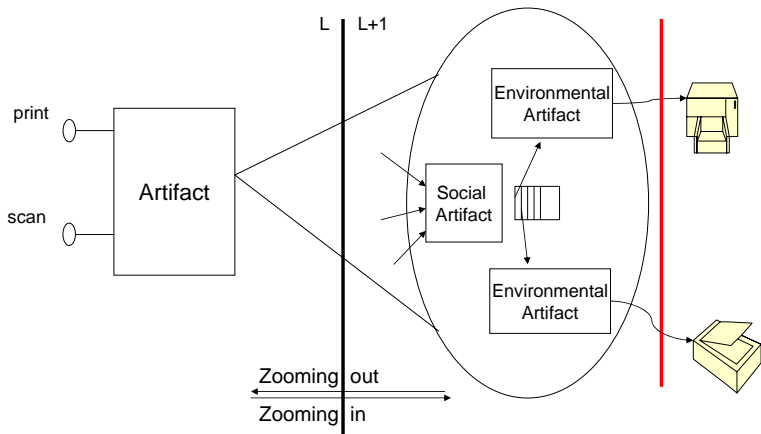
*Horizontal view:* analyse the system in one level of detail



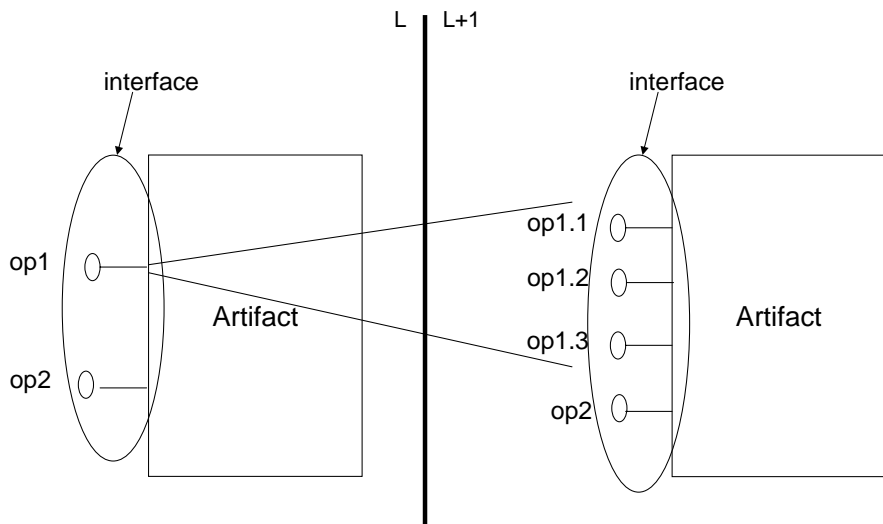
*Vertical view:* analyse one kind of abstract entity



# Zooming Artifact 1/2



# Zooming Artifact 2/2



# SODA

SODA is organised in two phase and each of them is composed of two steps:

- *Analysis phase:*
  - *Requirement Analysis:* the system's requirements and the external environment are analysed and modelled.
  - *Analysis:* the system's requirements are modelled in terms of tasks, functions, topologies and dependencies
- *Design phase:*
  - *Architectural Design phase:* in this phase we analyse the solution domain, the system is modelled in terms of roles, resources, actions, operations, interactions, workspaces and environment
  - *Detailed Design phase:* in this phase we design the system in terms of agents, societies, artifacts, composition of artifacts, workspaces and environment

# Outline

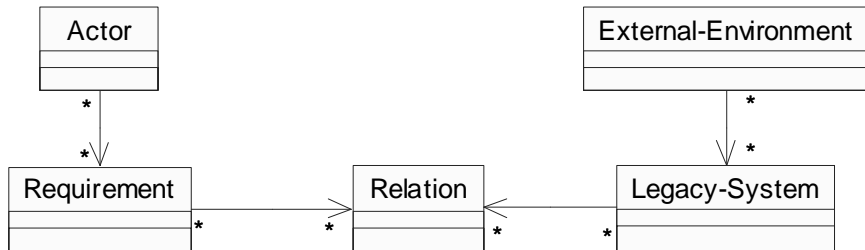
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# Requirements

The requirements can be categorised in:

- *Functional Requirement*: statements of services the system should provide, how the system should react to particular inputs and how the system should behave in particular situations.
- *Non-Functional Requirement*: constraints on the services or functions offered by the system such as timing constraints, constraints on the development process, standards, etc.
- *Domain Requirement*: requirements that come from the application domain of the system and that reflect characteristics of that domain.

# Requirement Analysis Meta-model



# Requirement Analysis

- *Actor* is a user of the systems that needs several functionalities from the systems. We use the system as an actor in order to express several non-functional requirements as security, standards and so on. The actors are used in order to facilitated the trace of the sources of requirements.
- *Requirement* is a functional, non-functional or domain description of the system service and constraint of the system.
- *External-Environment* is the external world of the system made by legacy systems that will interact with the system.
- *Legacy-System* is a single legacy system.
- *Relation* is a relationship among requirements and contexts.

# Requirement Analysis: Tabular Representation

- Requirements Tables:  $(L)AR_t$  and  $(L)Re_t$

Actor	Requirement
<i>actor name</i>	<i>requirement names</i>
Requirement	Description
<i>requirement name</i>	<i>requirement description</i>

- Domain Tables:  $(L)EELS_t$  and  $(L)LS_t$

External-Environment	Legacy-System
<i>external-environment name</i>	<i>Legacy-System names</i>
Legacy-System	Description
<i>legacy-system name</i>	<i>legacy-system description</i>

# Requirement Analysis: Tabular Representation

- Requirements Tables define and describe the abstract entities tied to the concept of “requirement” .
  - *Actor-Requirement Table*  $((L)AR_t)$  specifies the list of the requirements for each actors.
  - *Requirement Table*  $((L)Re_t)$  lists all the requirement and describe them.
- Domain Tables define and describe the abstract entities tied to the external environment.
  - *ExternalEnvironment-LegacySystem Table*  $((L)EELS_t)$  specifies the list of the contexts for external-environment.
  - *Legacy-System Table*  $((L)LS_t)$  lists all the contexts and describe them.

# Requirement Analysis: Tabular Representation

- Relations Tables:  $(L)Rel_t$ ,  $(L)RR_t$  and  $(L)RLS_t$

Relation	Description
<i>relation name</i>	<i>relation description</i>

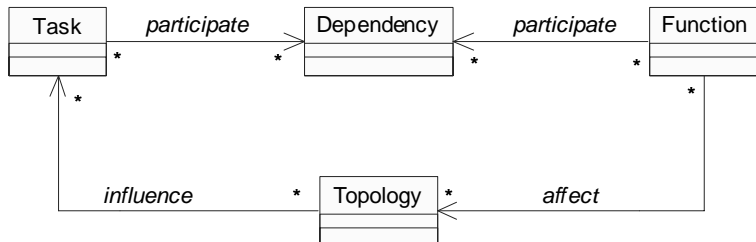
Requirement	Relation
<i>requirement name</i>	<i>relation names</i>

Legacy-System	Relation
<i>legacy-system name</i>	<i>relation names</i>

# Requirement Analysis: Tabular Representation

- Relations Tables relate the abstract entities among them.
  - *Relation Table*  $((L)Rel_t)$  lists all the relationship among abstract entities and provides a description to them.
  - *Requirement-Relation Table*  $((L)RR_t)$  specifies the list of relations where requirement is involved.
  - *LegacySystem-Relation Table*  $((L)LSR_t)$  specifies the list of relations where context is involved.

# Analysis Meta-model



# Analysis

- *Task*: is an activity that requires one or more competences and the use of functions.
- *Function*: is an reactive activity that aimed at supporting tasks.
- *Dependency*: is any relationship (interactions, constraints. . . ) among other (tasks and/or functions) abstract entities.
- *Topology*: is any topological necessity of the environment's structure, often could be derived from functions. It is important to note that topology could influence the tasks because topology could constrains the achievement of tasks.

# From Requirement Analysis to Analysis

- References Tables in top- down order:  $(L)RRT_t$ ,  $(L)RRF_t$ ,  $(L)RLSF_t$ ,  $(L)RLST_t$  and  $(L)RRD_t$

Requirement	Task
<i>requirement name</i>	<i>task names</i>

Requirement	Function
<i>requirement name</i>	<i>function names</i>

Legacy-System	Function
<i>legacy-system name</i>	<i>function names</i>

Legacy-System	Topology
<i>legacy-system name</i>	<i>topology names</i>

Relation	Dependency
<i>relation name</i>	<i>dependency names</i>

# from Requirement Analysis to Analysis

References Tables identify the relations among the abstractions of the requirement analysis phase and the abstractions used in analysis phase.

- *Reference Requirement-Task Table*  $((L)RRT_t)$  specifies the mapping between requirement and tasks.
- *Reference Requirement-Function Table*  $((L)RRF_t)$  specifies the mapping between requirement and resources.
- *Reference LegacySystem-Function Table*  $((L)RLSF_t)$  specifies the mapping between legacy-system and functions.
- *Reference LegacySystem-Topology Table*  $((L)RLST_t)$  specifies the mapping between legacy-system and topologies.
- *Reference Relation-Dependency Table*  $((L)RRD_t)$  specifies the mapping between relations and dependencies.

# Analysis: Tabular Representation

- Responsibilities Tables:  $(L)T_t$  and  $(L)F_t$

Task	Description
<i>task name</i>	<i>task description</i>

Function	Description
<i>function name</i>	<i>function description</i>

- Dependencies Tables:  $(L)D_t$ ,  $(L)TD_t$  and  $(L)FD_t$

Dependency	Description
<i>dependency name</i>	<i>dependency description</i>

Task	Dependency
<i>task name</i>	<i>dependency names</i>

Function	Dependency
<i>function name</i>	<i>dependency names</i>

# Analysis: Tabular Representation

- Responsibilities Tables define and describe the abstract entities tied to the concept of “responsibility” .
  - *Task Table*  $((L)T_t)$  lists all the tasks and describes them.
  - *Function Table*  $((L)F_t)$  lists all the functions and describe them.
- Dependencies Tables relate the abstract entities among them.
  - *Dependency Table*  $((L)D_t)$  lists all the dependency among abstract entities and provides a description to them.
  - *Task-Dependency Table*  $((L)TD_t)$  specifies the list of dependencies where task is involved.
  - *Function-Dependency Table*  $((L)FD_t)$  specifies the list of dependencies where function is involved.

# Analysis: Tabular Representation

- Topologies Tables in top – down order:  $(L)Top_t$ ,  $(L)TTop_t$ ,  $(L)FTop_t$

Topology	Description
<i>Topology name</i>	<i>topology description</i>

Task	Topology
<i>task name</i>	<i>topology names</i>

Function	Topology
<i>function name</i>	<i>topology names</i>

# Analysis: Tabular Representation

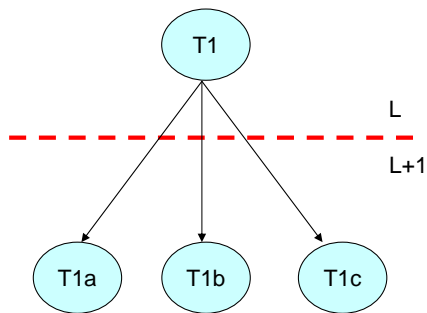
- Topologies Tables express the topological needs.
  - *Topology Table*  $((L)Top_t)$  lists all the topological requirements and provides a description to them.
  - *Task-Topology Table*  $((L)TTop_t)$  specifies the list of topological requirements those influence the task.
  - *Function-Topology Table*  $((L)FTop_t)$  specifies the list of topological requirements affected by the function.

# Zooming: Tabular Representation

- Zooming Table:  $(L)Z_t$

Layer L	Layer L+1
<i>out-zoomed entity</i>	<i>in-zoomed entities</i>

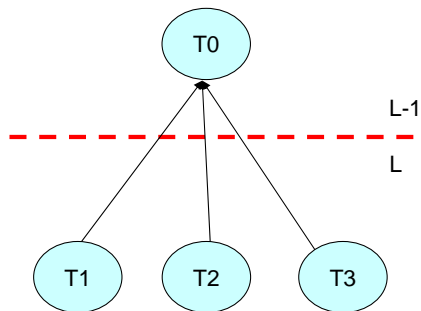
# Example: In-zoom task



- Zooming Table:  $(L)Z_t$

Layer L	Layer L+1
<i>T1</i>	<i>T1a, T1b, T1c, ...</i>

# Example: Out-zoom tasks



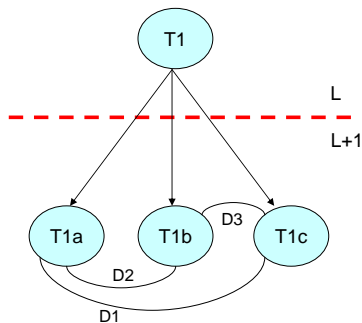
- Zooming Table:  $(L)Z_t$

Layer L-1	Layer L
$T_0$	$T_1, T_2, T_3, \dots$

# Important:

- The *organisational structure* of the system is **implicitly managed by means of zooming relation**
- For example when we in-zoom a task, we obtain new tasks, new dependencies and potentially new functions and topologies.
- By means of new dependencies we can express all the social rules that allow to new task to work together to achieve the original tasks.
- In the same way in the architectural design phase when we in-zoom a role, we obtain new roles, new actions, new interactions and potentially new resources and operations. By means of new interactions we can express all the social rules that allow to new roles to work together to achieve the “social task(s)” assigned to the original role.

# Complete Example: in-zoom task



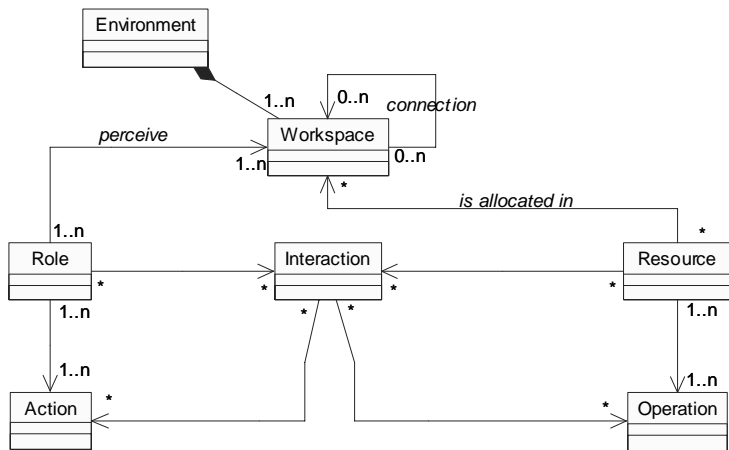
- Zooming Table:  $(L)Z_t$

Layer L	Layer L+1
$T1$	$T1a, T1b, T1c$ $D1, D2, D3$

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# Architectural Design Meta-model



# Architectural Design

- *Role*: is defined as the abstraction responsible for the achievement of one or more tasks.
- *Resource*: is defined as the abstraction that provides some functions.
- *Action*: represents an action that the role potentially could be able to do.
- *Operation*: represents the operation that the resource is potentially able to provide.
- *Interaction*: is defined as “rules” aimed to enable and bound both the behaviour of the abstract entities and the space of interactions. The bounds could be expressed by means of authorisation, prohibition and obligation concepts. Enabling could be expressed by means of rules that tie the actions with operations that support them.
- *Environment*: is the environment of the system.
- *Workspace*: is a conceptual locus in the environment.

# From Analysis to Architectural Design

- Transition Tables in top- down order:  $(L)TRT_t$ ,  $(L)TRF_t$ ,  $(L)TID_t$ ,  $(L)TTopW_t$

Role	Task
<i>role name</i>	<i>task names</i>
Resource	Function
<i>resource name</i>	<i>function names</i>
Dependency	Interaction
<i>dependency name</i>	<i>interaction names</i>
Topology	Workspace
<i>topology name</i>	<i>workspace names</i>

# From Analysis to Architectural Design

Transition Tables identify the relations among the abstractions of the requirement analysis phase and the abstractions used in analysis phase.

- *Transition Role-Task Table* ( $((L)TRT_t)$ ) specifies the mapping between tasks and roles.
- *Transition Resource-Function Table* ( $((L)TRF_t)$ ) specifies the mapping between functions and resources.
- *Transition Interaction-Dependency Table* ( $((L)TID_t)$ ) specifies the mapping between dependencies and interaction.
- *Transition Topology-Workplace Table* ( $((L)TTopW_t)$ ) specifies the mapping between topologies and workplaces.

# Architectural Design: Tabular Representation

- Entities Tables in top – down order:  $(L)A_t$ ,  $(L)O_t$ ,  $(L)RA_t$ ,  $(L)RO_t$

Action	Description
<i>action name</i>	<i>description</i>
Operation	Description
<i>operation name</i>	<i>description</i>
Role	Action
<i>role name</i>	<i>action names</i>
Resource	Operation
<i>resource name</i>	<i>operation names</i>

# Architectural Design: Tabular Representation

The Entities Tables that describe roles and resources of the system.

- *Action Table* ( $(L)A_t$ ) specifies the actions that roles could be able to execute and describes them the mapping between tasks and roles.
- *Operation Table* ( $(L)O_t$ ) specifies the operations that resources could provide and describes them the mapping between tasks and roles.
- *Role-Action Table* ( $(L)RA_t$ ) specifies the list of actions that a specific role is able to do.
- *Resource-Operation Table* ( $(L)RO_t$ ) specifies the list of operations that a specific resource is able to provide.

# Architectural Design: Tabular Representation

- Interactions Tables in top – down order:  $(L)I_t$ ,  $(L)Rol_t$ ,  $(L)Rel_t$

Interaction	Description
<i>interaction name</i>	<i>description</i>
Role	Interaction
<i>role name</i>	<i>interaction names</i>
Resource	Interaction
<i>resource name</i>	<i>interaction names</i>

# Architectural Design: Tabular Representation

The Interactions Tables that describe the interaction where roles and resources are involved.

- *Interaction Table*  $((L)I_t)$  specifies the interactions and describes them. the mapping between tasks and roles.
- *Role-Interaction Table*  $((L)Rol_t)$  specifies the list of interactions where roles are involved
- *Resource-Interaction Table*  $((L)Rel_t)$  specifies the list of interactions where resources are involved

# Architectural Design: Tabular Representation

- Topological Tables in top-down order:  $(L)W_t$ ,  $(L)WC_t$ ,  $(L)WRe_t$  and  $(L)WRO_t$

Workspace	Description
<i>workspace name</i>	<i>description</i>
Workspace	Connection
<i>workspace name</i>	<i>workspace names</i>
Workspace	Resource
<i>workspace name</i>	<i>resource names</i>
Role	Workspace
<i>role name</i>	<i>workspace names</i>

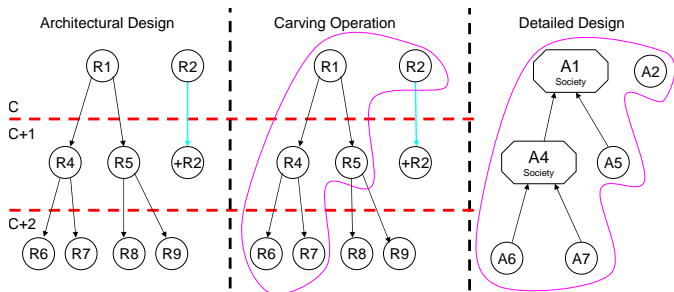
# Architectural Design: Tabular Representation

## Topological Tables:

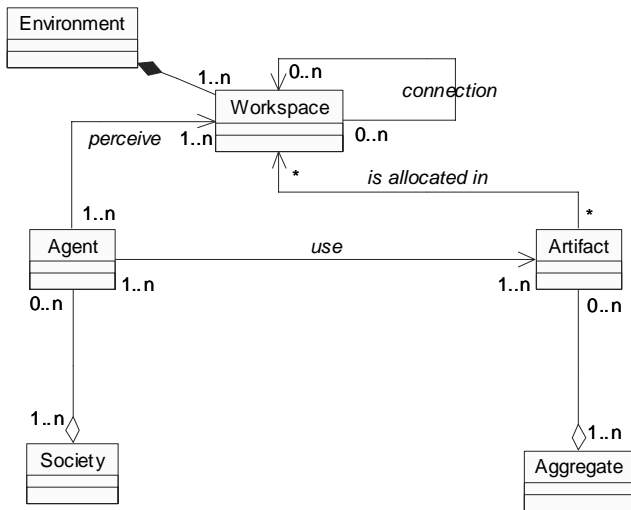
- *Workspace Table*  $((L)W_t)$  specifies the workspaces and describes them.
- *Workspace-Connection Table*  $((L)WC_t)$  shows the connections between workspaces at the same layer of abstraction (the hierarchical relations among workspaces are managed by means of zooming table)
- *Workspace-Resource Table*  $((L)WRe_t)$  shows the allocation of the resources to workspaces. A resource could be allocated in several different workspaces. In particular, a single, distributed resource can in principle be used to model a distributed service, accessible from more nodes of the network.
- *Workspace-Role Table*  $((L)WRo_t)$  shows the list of workspace that the roles can perceive in the system.

# Design views

- In this phase potentially our system could be composed by all the layers detected in the previously steps.
- But the deliverable of the Detailed Design step will be composed of only one layer
- So, for each entity, we choose the appropriate layer of representation:



## Detailed Design Phase Meta-model



# Detailed Design

- *Agent*: is an autonomous entity able to play several roles.
- *Society*: is defined as the abstraction responsible for a collection of agents.
- *Artifact*: is an object able to provides several service.
- *Aggregate*: is defined as the abstraction responsible for a collection of artifacts.
- *Environment*: is the environment of the system.
- *Workspace*: is a conceptual locus in the environment.

# From Architectural Design to Detailed Design

- Mapping Tables in top- down order:  $(L)MAR_t$ ,  $(L)MArR_t$ ,  $(L)MArI_t$

Agent	Role
<i>agent name</i>	<i>role names</i>
(Environmental) Artifact	Resource
<i>artifact name</i>	<i>resource names</i>
Interaction	(Social) Artifact
<i>interaction name</i>	<i>artifact names</i>

# From Architectural Design to Detailed Design

## Mapping Tables:

- *Mapping Agent-Role* ( $(L)MAR_t$ ) maps roles onto the agents
- *Mapping Artifact-Resource Table* ( $(L)MArR_t$ ) maps resources onto the artifacts.
- *Mapping Artifact-Interaction Table* ( $(L)MAI_t$ ) maps the rules specified in architectural design onto the artifacts that improve them.

# Detailed Design: Tabular Representation

- Agent/Society Design Tables in top- down order:  $(L)AA_t$ ,  $(L)SA_t$ ,  $(L)SAr_t$

Agent	(Individual) Artifact
<i>agent name</i>	<i>artifact names</i>
Society	Agent
<i>society name</i>	<i>agent names</i>
Society	(Social)Artifact
<i>society name</i>	<i>artifact names</i>

# Detailed Design: Tabular Representation

## Agent/Society Design Tables:

- *Agent-Artifact Table*  $((L)AA_t)$  specifies the (individual) artifacts related to agents.
- *Society-Agent Table*  $((L)SA_t)$  specifies which agents work in the society
- *Society-Artifact Table*  $((L)SAr_t)$  specifies the (social) artifacts related to societies.

# Detailed Design: Tabular Representation

- Environment Design Tables in top- down order:  $(L)AUI_t$ ,  $(L)AggA_t$ ,  $(L)WA_t$

Artifact	Usage Interface
<i>artifact name</i>	<i>list of operations</i>
Aggregate	Artifact
<i>aggregate name</i>	<i>artifact names</i>
Workspace	Artifact
<i>workspace name</i>	<i>artifact names</i>

# Detailed Design: Tabular Representation

## Environment Design Tables:

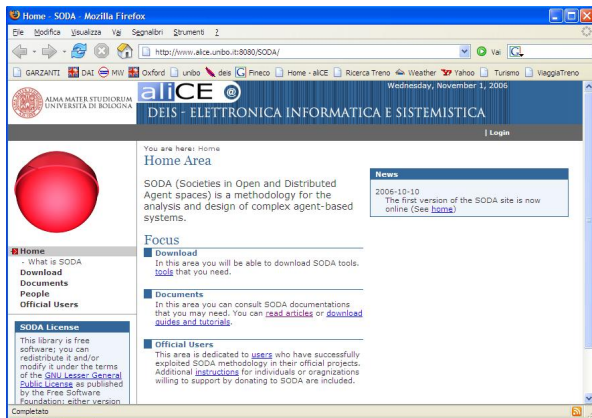
- *Artifact-UsageInterface Table*  $((L)AUI_t)$  specifies the operations provided by artifacts.
- *Aggregate-Artifact Table*  $((L)AggA_t)$  specifies which artifact compose the composition.
- *Workspace-Artifact Table*  $((L)WA_t)$  specifies the artifact located in the workspace

# Outline

- 1 SODA: Agents and Artifacts Meta-Model and Layering Principle
  - Agents and Artifacts Meta-model
  - Principles and Mechanisms
- 2 The SODA Methodology
  - Analysis Phase
  - Design Phase
  - Web Resources and Conclusions

# WebSite

- <http://www.alice.unibo.it/soda/>



The screenshot shows a Mozilla Firefox browser window displaying the website <http://www.alice.unibo.it/soda/>. The browser's address bar shows the URL. The website header features the Alice logo and the text "ALICE @ DEIS - ELETTRONICA INFORMATICA E SISTEMISTICA" along with the date "Wednesday, November 1, 2006". A navigation menu includes "Home", "Download", "Documents", "People", and "Official Users". The main content area is titled "Home Area" and includes a "SODA License" section, a "Focus" section with sub-sections for "Download", "Documents", and "Official Users", and a "News" section. The "SODA License" section states that the library is free software and can be redistributed under the terms of the GNU Lesser General Public License. The "Focus" section provides links to "read articles" and "download guides and tutorials". The "News" section mentions the first version of the SODA site is now online.

# Conclusions and Future Works

- SODA allows to
  - design societies
  - design environments
  - support the complexity of system description (layering principle)
- Future works
  - refining the meta-model
  - modeling SODA according to SPEM (Software Process Engineering Meta-Model)
  - extracting fragments from SODA according to IEEE-FIPA Method Engineering

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# The SODA Methodology

Multiagent Systems LS  
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