The SODA AOSE Methodology
Multiagent Systems LS
Sistemi Multiagente LS

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Ingegneria Due
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SODA: Societies in Open and Distributed Agent spaces

SODA ...

- is an agent-oriented methodology for the analysis and design of agent-based systems
- focuses on inter-agent issues, like the engineering of societies and environment for MAS [Omicini, 2001]
- adopts agents and artifacts – after the A&A meta-model – as the main building blocks for MAS development [Molesini et al., 2005]
- introduces a simple layering principle in order to cope with the complexity of system description [Molesini et al., 2006]
- adopts a tabular representation
A methodology is a collection of methods covering and connecting different stages in a process.

The purpose of a methodology is to prescribe a certain coherent approach to solving a problem in the context of a software process by preselecting and putting in relation a number of methods.

A methodology has two important components:

- one that describes the process elements of the approach: the abstractions
- one that focuses on the steps that have to be done, the work products that have to be produced – and their documentation –...: the process.
The abstractions supported by SODA are logically divided into three categories:

- the abstractions for modelling/designing the system active part (task, role, agent, etc.);
- the abstractions for the reactive part (function, resource, artifact, etc.);
- the abstractions for interaction and organisational rules (relation, dependency, interaction, rule, etc.).

Each of the four SODA’s steps models the system by exploiting a specific subset of the abstractions:

- each subset always includes at least one abstraction for each of the above categories: at least one abstraction for the system active part, one for the reactive part, and another for interaction and organisational rules.
SODA Active Abstractions

Requirement → Task → Role → Society → Agent

Requirement → Task → Action → Role → Society → Agent
SODA Reactive Abstractions

Diagram:
- Requirement
- Legacy-System
- Function
- Topology
- Resource
- Operation
- Space
- Aggregate
- Artifact
- Workspace

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SODA A.Y. 2008/2009
SODA Interaction & Normative Abstractions
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 by agents

**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
Classification

A possible classification for artifacts

**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 MAS 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** — 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.
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
A&A Ingredients in SODA

**Agents** model individual and social activities

**Artifacts** *glue* agents together, as well as MAS and the environment
- artifacts mediate between individual agents and MAS
- artifacts build up agent societies
- artifacts wrap up the resources of MAS and bring them to the cognitive level of agents

**Workspaces** structure agents and artifacts organisation & interaction
SODA Abstractions: A Formal Representation?

- How can we represent the SODA abstractions? ...
- ...and their relationships? ...
- ...in a standard way in order to support methodologies comparisons? ...
- The meta-modelling technique from Software Engineering can help us
Meta-models for Software Engineering Methodologies

**Definition**

Meta-modelling is the analysis, construction and development of the frames, rules, constraints, models and theories applicable and useful for the modelling in a predefined class of problems.

- A meta-model enables checking and verifying the completeness and expressiveness of a methodology by understanding its deep semantics, as well as the relationships among concepts in different languages or methods.
- The process of designing a system consists of instantiating the system meta-model that the designers have in their mind in order to fulfill the specific problem requirements [Bernon et al., 2004].
Using Meta-models

- Meta-models are useful for specifying the concepts, rules and relationships used to define a family of related methodologies.
- Although it is possible to describe a methodology without an explicit meta-model, formalising the underpinning ideas of the methodology in question is valuable when checking its consistency or when planning extensions or modifications.
- Meta-models are often used by methodologists to construct or modify methodologies.
Meta-models & Methodologies

- Methodologies are used by software development teams to construct software products in the context of software projects.
- Meta-model, methodology and project constitute, in this approach, three different areas of expertise that, at the same time, correspond to three different levels of abstraction and three different sets of fundamental concepts.
- As the work performed by the development team at the project level is constrained and directed by the methodology in use, the work performed by the methodologist at the methodology level is constrained and directed by the chosen meta-model.
- Traditionally, these relationships between *modelling layers* are seen as instance-of relationships, in which elements in one layer are instances of some element in the layer above.
SODA Abstractions Adopted at Each Step

- **Analysis phase**
  - *Requirements 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* — in this phase we analyse the solution domain, the system is modelled in terms of roles, resources, actions, operations, interactions, rules and spaces
  - *Detailed Design* — in this phase we design the system in terms of agents, societies, artifacts, compositions, aggregates, workspaces, uses, links to, manifests and speaks to
Requirements Analysis Meta-model

SODA: Abstractions
The SODA meta-model

Actor
Requirement
1
* participates

Relation
participates

LegacySystem
ExternalEnvironment
1
* participates

Requirement

Actor

ExternalEnvironment

LegacySystem

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SODA
A.Y. 2008/2009
Requirements 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.
Analysis Meta-model

Task \rightarrow \text{participates} \rightarrow \text{Dependency} \rightarrow \text{participates} \rightarrow \text{Function}

Task \rightarrow \text{participates} \rightarrow \text{Topology} \rightarrow \text{participates} \rightarrow \text{Function}

Requirements Analysis
Analysis Architectural Design
Architectural Design Detailed Design
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.
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 — represents the acts of the interaction among roles, among resources and between roles and resources

Rule — enables and bounds the entities’ behaviour

Space — is a conceptual locus in the environment
**Detailed Design**

**Agent** — is an autonomous entity able to play several roles

**Society** — is a group of interacting agents and artifacts when its overall behaviour is essentially an *autonomous*, proactive one.

**Artifact** — is a group of interacting agents and artifacts when its overall behaviour is essentially a *functional*, reactive one.

**Aggregate** — is defined as the abstraction responsible for a collection of artifacts

**Workspace** — is a conceptual locus in the environment

**Uses** — the act of interaction between agent and artifact: agent uses artifact

**Speaks to** — the act of interaction among agents: agent speaks with another agent

**Manifests** — the act of interaction between artifact and agent: artifact manifests itself to agent

**Links to** — the act of “interaction” among artifact: artifact is linked to another artifact
Development Process

**Development Process [Cernuzzi et al., 2005]**

- The *development process* is an ordered set of steps that involve all the activities, constraints and resources required to produce a specific desired output satisfying a set of input requirements.

- Typically, a process is composed by different stages/phases put in relation with each other.

- Each stage/phase of a process identify a portion of work definition to be done in the context of the process, the resources to be exploited to that purpose and the constraints to be obeyed in the execution of the phase.

- Case by case, the work in a phase can be very small or more demanding.

- Phases are usually composed by a set of activities that may, in turn, be conceived in terms of smaller atomic units of work (steps).
Software Process

The software development process is the coherent set of policies, organisational structures, technologies, procedures and deliverables that are needed to conceive, develop, deploy and maintain a software product.

The software process exploits a number of contributions and concepts [Fuggetta, 2000]

Software development technology — Technological support used in the process. Certainly, to accomplish software development activities we need tools, infrastructures, and environments.

Software development methods and techniques — Guidelines on how to use technology and accomplish software development activities. The methodological support is essential to exploit technology effectively.

Organisational behavior — The science of organisations and people.

Marketing and economy — Software development is not a self-contained endeavor. As any other product, software must address real customers’ needs in specific market settings.
SPEM (Software Process Engineering Meta-model) [Object Management Group, 2008] is an OMG standard object-oriented meta-model defined as an UML profile and used to describe a concrete software development process or a family of related software development processes.

SPEM is based on the idea that a software development process is a collaboration between active abstract entities called roles which perform operations called activities on concrete and real entities called work products.

Each role interacts or collaborates by exchanging work products and triggering the execution of activities.

The overall goal of a process is to bring a set of work products to a well-defined state.
The goals of SPEM are to

- support the representation of one specific development process
- support the maintenance of several unrelated processes
- provide process engineers with mechanisms to consistently and effectively manage whole families of related processes promoting process reusability
Standardize representation and manage libraries of reusable **Method Content**

- Content on agile development
- Content on managing iterative development
- Guidance on serialized java beans
- JUnit user guidance
- Content on J2EE
- Configuration mgmt guidelines

**Process**

Develop and manage **Processes** for performing projects

- Process for Custom Application Development with J2EE
- Process for Embedded System Development
- Process for SOA Governance

**Configure** a cohesive process framework customized for my project needs

**Enactment** of process in the context of my project
Clear separation between

- **Method Contents** — introduce the concepts to document and manage development processes through natural language description
- **Processes** — defines a process model as a breakdown or decomposition of nested Activities, with the related Roles and input / output Work Products
- **Capability patterns** — reusable best practices for quickly creating new development processes
SPEM: Method Content and Process
## SPEM Notation

<table>
<thead>
<tr>
<th>Stereotype</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>Activity</td>
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</tr>
<tr>
<td>Category</td>
<td><img src="image" alt="Category Symbol" /></td>
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<tr>
<td>Composite role and Team</td>
<td><img src="image" alt="Composite role and Team Symbol" /></td>
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<tr>
<td>Guidance</td>
<td><img src="image" alt="Guidance Symbol" /></td>
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<td>Milestone</td>
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<td>Process</td>
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<td>Process Pattern</td>
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<td>Role Definition and Use</td>
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<td>Tool Definition</td>
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<td>WorkProduct Definition and Use</td>
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Layering: The Intuition

A complex system

is any system featuring a large number of interacting components, whose aggregate activity is nonlinear and typically self-organisation [Simon, 1996].

The human mind

is not able to reason about

- a great number of different components / parts
- too many details...

We need

- models...
- ... capturing the systems’details at different levels of abstraction
Layering: The Intuition I
Layering: The Intuition II

Diagram:
- Agent
- Artifact
- Artifact
- Artifact

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Managing Complexity

- Complexity is inherent in real-life systems
- Complexity management: balancing between *completeness* and *clarity*
- Analysis and design of real-life systems proceed *middle-out*
- Complex systems call for *layered*, hierarchical explanations
- Each layer is in some sense autonomous
  - at the same time, layers are organised in a hierarchy
  - each layer is strictly connected with the upper /lower layers
Layering, Systems & MAS

- 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 MAS, 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

- The layering principle is achieved by means of the zoom and projection mechanisms [Molesini et al., 2006, Molesini et al., 2008a]

- Two kinds of zoom
  - **in-zoom** — from an abstract to a more detailed layer
  - **out-zoom** — from a detailed to a more abstract layer

- The *projection mechanism* projects entities from one to another layer
Layering in SODA: Process

- In-zoom
- Out-zoom
- Projection
- Select Layer

new layer?

- yes: increases detail
- no: increases abstraction

New layer?

- yes: Select Layer
- no: End

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Layering Principle

- In general, when working with SODA, we start from a certain layer, we could call \textit{core layer}, and it is labelled with “c”
- The core layer is always \textbf{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 \textit{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

The SODA Process Mechanisms

Core Layer

C-1

C+1

C+2

E9

E8

E7

E6

E5

E4

E3

E2

E1

E0

-E1

+E2

+E2

+E2

+E2
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

interface

op1

Artifact

op2

L

L+1

interface

op1.1

op1.2

op1.3

op2

Artifact

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SODA Process Organisation

- Four sub-phases: Requirements Analysis, Analysis, Architectural Design, Detailed Design
- Each sub-phase is modelled as a separate and independent Method Content
- A specific process is defined for each sub-phase
- Reusing of these processes to create the whole SODA process
- Each sub-phase – and each model in the sub-processes – is represented as an activity, related to the corresponding SPEM’s Task in the specific Method Content
- Adoption of the Layering Capability pattern
The SODA Process [Molesini et al., 2008b]

1. Requirements Analysis
2. Analysis
3. Layering
4. Architectural Design
5. Detailed Design

- Is the problem well specified? (no → Layering; yes → Analysis)
- Is the system well specified? (no → Layering; yes → Architectural Design)
- Are there problems in the system? (no → Detailed Design; yes → Architectural Design)

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Requirements Analysis Process

- Requirements modelling
- Environment modelling
- Relations modelling
- Requirements layering
- Environment layering
- Relations layering

Are the models well specified?
- yes
- no

Start new iteration if the models are not well specified.

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Requirements Analysis Process

- **Requirements modelling** activity: *requirement* and *actor* are used for modelling the customers’ requirements and the requirement sources.

- **Environment modelling** activity: *external-environment* notion is used as a container of the *legacy-systems* that represent the legacy resources of the environment.

- **Relation modelling** activity: *relation* is used for modelling the relationships between requirements and legacy systems.
Analysis Process

- Moving from requirements
- Task analysis
- Function analysis
- Topology analysis
- Dependency analysis

- Task layering
- Function layering
- Topology layering
- Dependency layering

- other layer?
- new iteration
- Are the models well specified?

- yes
- no

- another layer?

- yes
- no
Analysis Process

- **Moving from Requirements** activity: the abstractions identified in the previous step are mapped onto the abstractions adopted in this stage to generate the initial version of the Analysis models.

- **Task analysis** activity: task is exploited for analysing the system’s active part.

- **Function analysis** activity: function is exploited for analysing the system’s functional part.

- **Topology analysis** activity: topology is exploited for analysing the topological constraints over the environment.

- **Dependency analysis** activity: dependency is exploited for the analysis of the relations highlighted in the previous step and for the definition of new relationship among abstract entities identified in this stage.
Architectural Design Process
Architectural Design Process

- **Transition** activity: the abstractions identified in the previous step are mapped onto the abstractions adopted in this stage so as to generate the initial version of the Architectural Design models.

- **Role design** activity: assignment tasks to *roles* and identification of the *actions* necessary in order to achieve each specific task.

- **Resource design** activity: assignment of functions of responsibilities for providing to *resources* and identification of the *operations* necessary for providing each specific function.

- **Space design** activity: identification of the *spaces* starting from the topology constraints analysed in the previous step.

- **Interaction design** activity: identification of the *interactions* that represent the acts of the interaction among roles, among resources and between roles and resources starting from the dependencies analysed in the previous step.

- **Constraint design** activity: identification of the *rules* that enable and bound the entities’ behaviour starting from the dependencies analysed in the previous step.
Detailed Design Process

Carving

Mapping

Agent design
Environment design
Workspace design

Interactions design

is the system well specified?

yes

no
Carving

- In the Architectural Design step our system could be potentially composed by all the layers detected in the previously steps
- Each complete layer represents a different system architecture...
- It is not possible to first design and then physically implement a system specified by different levels of abstraction
- So, for each entity, we need to choose the appropriate layer of representation...
- ... the chosen system architecture is “carved out” from all the possible architectures
- So, each carving represents a specific development...
- ... in an iterative incremental process we can made different carving in order to refine the system
Carving

Architectural Design

R1 → R2 → R4 → R6 → R8 → R9
R1 → R2 → R5 → R6 → R7 → R8
R1 → R2 → R5 → R6 → R7 ← R9

Architectural Design

Carving Operation

R1 → R2 → R4 → R6 → R7 → R8 → R9
R1 → R2 → R5 → R6 → R7 → R8
R1 → R2 → R5 → R6 → R7 ← R9
Detailed Design Process

- Mapping activity: the carved abstractions are mapped onto the abstractions adopted in this stage, thus generating the initial version of the Detailed Design models
- Agent design activity: design of agents and societies
- Environment design activity: design of artifacts and aggregates
- Workspace design activity: design of workspaces
- Interactions design activity: design of uses, manifests, speaks to and links to
The design of a complex system calls for both a clear and disciplined notation and tools for supporting the consistency checks.

- SODA adopts a tabular representation
- Tables
  - clear way for analysing and designing the systems
  - very easy for automatic tools
  - very easy for consistency and completeness checkers
Analysis Phase: Tables

- Requirements Analysis
- References Tables
- Domain Tables
- Relations Tables
- Analysis
- Responsibilities Tables
- Dependencies Tables
- Topologies Tables
- Transitions Tables
Requirements Analysis: Tabular Representation

- **Requirements Tables**: $(L)Ac_t$, $(L)AR_t$ and $(L)Re_t$

<table>
<thead>
<tr>
<th>Actor</th>
<th>Description</th>
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<tbody>
<tr>
<td>actor name</td>
<td>actor description</td>
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<table>
<thead>
<tr>
<th>Actor</th>
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<tbody>
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<table>
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<tr>
<th>Requirement</th>
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<tbody>
<tr>
<td>requirement name</td>
<td>requirement description</td>
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- **Domain Tables**: $(L)EELS_t$ and $(L)LS_t$

<table>
<thead>
<tr>
<th>External-Environment</th>
<th>Legacy-System</th>
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<tr>
<td>external-environment name</td>
<td>Legacy-System names</td>
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<table>
<thead>
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<th>Legacy-System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>legacy-system name</td>
<td>legacy-system description</td>
</tr>
</tbody>
</table>
Requirements Analysis: Tabular Representation

- Requirements Tables define and describe the abstract entities tied to the concept of “requirement”
  - Actor table \((L)\text{Ac}_t\) describes each single actor
  - Actor-Requirement Table \((L)\text{AR}_t\) specifies the list of the requirements for each actor
  - Requirement Table \((L)\text{Re}_t\) lists all the requirement and describe them.

- Domain Tables define and describe the abstract entities tied to the external environment
  - ExternalEnvironment-LegacySystem Table \((L)\text{EELS}_t\) specifies the list of the contexts for external-environment
  - Legacy-System Table \((L)\text{LS}_t\) lists all the contexts and describe them
Requirements Analysis: Tabular Representation

- Relations Tables: \((L)\text{Rel}_t\), \((L)\text{RR}_t\) and \((L)\text{RLS}_t\)

<table>
<thead>
<tr>
<th>Relation</th>
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<tbody>
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<td>relation names</td>
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<th>Legacy-System</th>
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</thead>
<tbody>
<tr>
<td>legacy-system name</td>
<td>relation names</td>
</tr>
</tbody>
</table>
Requirements 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
### From Requirements Analysis to Analysis (II)

- References Tables in top-down order: 
  
  - \((L)RRT_t\), \((L)RRF_t\), \((L)RRT_{ot}\), 
  
  \((L)RReqD_t\), \((L)RLSF_t\), \((L)RLST_t\), \((L)RRelD_t\)

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Task</th>
<th>Requirement name</th>
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<td>Requirement</td>
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<tr>
<td>Requirement</td>
<td>Topology</td>
<td>requirement name</td>
<td>topology names</td>
</tr>
<tr>
<td></td>
<td></td>
<td>requirement name</td>
<td></td>
</tr>
<tr>
<td>Requirement</td>
<td>Dependency</td>
<td>requirement name</td>
<td>dependency names</td>
</tr>
<tr>
<td>Legacy-System</td>
<td>Function</td>
<td>legacy-system name</td>
<td>function names</td>
</tr>
<tr>
<td>Legacy-System</td>
<td>Topology</td>
<td>legacy-system name</td>
<td>topology names</td>
</tr>
<tr>
<td>Legacy-System</td>
<td>Dependency</td>
<td>legacy-system name</td>
<td>dependency names</td>
</tr>
<tr>
<td>Relation</td>
<td>Dependency</td>
<td>relation name</td>
<td>dependency names</td>
</tr>
</tbody>
</table>
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 Requirement-Topology table** $(L)RRT_0_t$ specifies the mapping between each requirement and the generated topologies
- **Reference Requirement-Dependency table** $(L)RReqD_t$ specifies the mapping between each requirement and the generated dependencies
- **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 \((L)F_t\)

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>task name</td>
<td>task description</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>function name</td>
<td>function description</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Dependency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dependency name</td>
<td>dependency description</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Task</th>
<th>Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td>task name</td>
<td>dependency names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Function</th>
<th>Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td>function name</td>
<td>dependency names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topology</th>
<th>Dependency</th>
</tr>
</thead>
<tbody>
<tr>
<td>topology name</td>
<td>dependency names</td>
</tr>
</tbody>
</table>
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.
  - Topology-Dependency table \((L)TopD_t\) specifies the list of dependencies where each topology is involved.
Analysis: Tabular Representation

- Topologies Tables in top-down order – \((L)\text{Top}_t, (L)\text{TTop}_t, (L)\text{FTop}_t\)

<table>
<thead>
<tr>
<th>Topology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topology name</td>
<td>topology description</td>
</tr>
<tr>
<td>Task</td>
<td>Topology</td>
</tr>
<tr>
<td>task name</td>
<td>topology names</td>
</tr>
<tr>
<td>Function</td>
<td>Topology</td>
</tr>
<tr>
<td>function name</td>
<td>topology names</td>
</tr>
</tbody>
</table>

- Topologies Tables express the topological needs
  - *Topology Table* \((L)\text{Top}_t\) lists all the topological requirements and provides a description to them.
  - *Task-Topology Table* \((L)\text{TTop}_t\) specifies the list of topological requirements those influence the task.
  - *Function-Topology Table* \((L)\text{FTop}_t\) specifies the list of topological requirements affected by the function.
Zooming: Tabular Representation

- Zooming Table: \((L)Z_t\)

<table>
<thead>
<tr>
<th>Layer L</th>
<th>Layer L+1</th>
</tr>
</thead>
<tbody>
<tr>
<td>out-zoomed entity</td>
<td>in-zoomed entities</td>
</tr>
</tbody>
</table>
Example: In-zoom Task

Zooming Table: $\,(L)Z_t$

<table>
<thead>
<tr>
<th>Layer L</th>
<th>Layer $L+1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T1$</td>
<td>$T1a, T1b, T1c, \ldots$</td>
</tr>
</tbody>
</table>
Example: Out-zoom Tasks

Zooming Table: $(L)Z_t$

<table>
<thead>
<tr>
<th>Layer L-1</th>
<th>Layer L</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T0$</td>
<td>$T1, T2, T3, \ldots$</td>
</tr>
</tbody>
</table>
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: \((L)Z_t\)

<table>
<thead>
<tr>
<th>Layer L</th>
<th>Layer L+1</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T1)</td>
<td>(T1a, T1b, T1c)</td>
</tr>
<tr>
<td></td>
<td>(D1, D2, D3)</td>
</tr>
</tbody>
</table>
Design Phase: Tables

Transitions Tables

Architectural Design
- Entities Tables
- Interaction Tables
- Constraints Tables
- Topological Tables

Mapping Tables

Detailed Design
- Agent/Society Design Tables
- Environment Design Tables
- Interaction Design Tables
- Topological Design Tables
# From Analysis to Architectural Design

Transition Tables in top-down order – $(L)\ TRT_t$, $(L)\ TTA_t$, $(L)\ TRF_t$, $(L)\ TFO_t$, $(L)\ TID_t$, $(L)\ TTopS_t$

<table>
<thead>
<tr>
<th>Role</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>role name</td>
<td>task names</td>
</tr>
<tr>
<td>Task</td>
<td>Action</td>
</tr>
<tr>
<td>task name</td>
<td>action names</td>
</tr>
<tr>
<td>Resource</td>
<td>Function</td>
</tr>
<tr>
<td>resource name</td>
<td>function names</td>
</tr>
<tr>
<td>Function</td>
<td>Operation</td>
</tr>
<tr>
<td>function name</td>
<td>operation names</td>
</tr>
<tr>
<td>Dependency</td>
<td>Interaction</td>
</tr>
<tr>
<td>dependency name</td>
<td>interaction names</td>
</tr>
<tr>
<td>Dependency</td>
<td>Rule</td>
</tr>
<tr>
<td>dependency name</td>
<td>rule names</td>
</tr>
<tr>
<td>Topology</td>
<td>Space</td>
</tr>
<tr>
<td>topology name</td>
<td>space names</td>
</tr>
</tbody>
</table>
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 Task-Action table \((L) TTA_t\) relates tasks and actions.
- Transition Resource-Function Table \((L) TRF_t\) specifies the mapping between functions and resources.
- Transition Function-Operation table \((L) TFO_t\) relates functions and operations.
- Transition Interaction-Dependency Table \((L) TID_t\) specifies the mapping between dependencies and interaction.
- Transition Rule-Dependency table \((L) TRuD_t\) maps dependencies onto rules
- Transition Topology-Space Table \((L) TTopS_t\) specifies the mapping between topologies and spaces.
Architectural Design: Tabular Representation

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

<table>
<thead>
<tr>
<th>Action</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>action name</td>
<td>description</td>
</tr>
<tr>
<td>Operation</td>
<td>Description</td>
</tr>
<tr>
<td>operation name</td>
<td>description</td>
</tr>
<tr>
<td>Role</td>
<td>Action</td>
</tr>
<tr>
<td>role name</td>
<td>action names</td>
</tr>
<tr>
<td>Resource</td>
<td>Operation</td>
</tr>
<tr>
<td>resource name</td>
<td>operation names</td>
</tr>
</tbody>
</table>
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 – \((L)I_t, (L)Acl_t, (L)Opl_t\)

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>interaction name</td>
<td>description</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Action</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>action name</td>
<td>interaction names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operation</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>operation name</td>
<td>interaction names</td>
</tr>
</tbody>
</table>
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.
- *Action-Interaction table* \((L)Acl_t\) specifies the interactions where each action is involved.
- *Operation-Interaction table* \((L)Opl_t\) specifies the interactions where each operation is involved.
Architectural Design: Tabular Representation

- Constraints Tables in top-down order – $(L)Ru_t$, $(L)IRu_t$, $(L)ReRu_t$, $(L)RoRu_t$, $(L)SRu_t$

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>rule name</td>
<td>description</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>interaction name</td>
<td>rule names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>resource name</td>
<td>rule names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Role</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>role name</td>
<td>rule names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Space</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>space name</td>
<td>rule names</td>
</tr>
</tbody>
</table>
The Constraints Tables describe the constraints over the entities behaviours

- **Rule table** ($(L)Ru_t$) defines the single rule.
- **Rule-Interaction table** ($(L)IRu_t$) specifies the constraints over the interactions.
- **Resource-Rule table** ($(L)ReRu_t$) specifies the rules where each resource is involved.
- **Role-Rule table** ($(L)RoRu_t$) specifies the rules where each role is involved.
- **Space-Rule table** ($(L)SRu_t$) specifies the rules where each space is involved.
Architectural Design: Tabular Representation

- Topological Tables in top-down order – $(L)S_t$, $(L)SC_t$, $(L)SRe_t$ and $(L)SRo_t$

<table>
<thead>
<tr>
<th>Space</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>space name</td>
<td>description</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Space</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>space name</td>
<td>space names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>resource name</td>
<td>space names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Role</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>role name</td>
<td>space names</td>
</tr>
</tbody>
</table>
Architectural Design: Tabular Representation

- **Topological Tables**
  - *Space table* \( (L)S_t \) specifies the spaces and describes them.
  - *Space-Connection table* \( (L)SC_t \) shows the connections between spaces at the same layer of abstraction (the hierarchical relations among spaces are managed by means of zooming table).
  - *Space-Resource table* \( (L)SRe_t \) shows the allocation of the resources to spaces. A resource could be allocated in several different spaces. In particular, a single, distributed resource can in principle be used to model a distributed service, accessible from more nodes of the network.
  - *Space-Role table* \( (L)sRo_t \) shows the list of space that the roles can perceive in the system.
From Architectural Design to Detailed Design

- Mapping Tables in top-down order – $MAR_t$, $MSR_t$, $MAAc_t$, $MArR_t$, $MAggR_t$, $MArOp_t$, $MArRu_t$, $MSW_t$, $MIU_t$, $MIM_t$, $MISp_t$, $MIL_t$

<table>
<thead>
<tr>
<th>Agent</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>agent name</td>
<td>role names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Society</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>society name</td>
<td>role name</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Individual) Artifact</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>artifact name</td>
<td>action names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Environmental) Artifact</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>artifact name</td>
<td>resource names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>aggregate name</td>
<td>resource name</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Environmental) Artifact</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>artifact name</td>
<td>operation names</td>
</tr>
</tbody>
</table>
From Architectural Design to Detailed Design

<table>
<thead>
<tr>
<th>Rule</th>
<th>Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>rule name</td>
<td>artifact names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workspace</th>
<th>Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>workspace name</td>
<td>space names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>interaction name</td>
<td>use names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Manifest</th>
</tr>
</thead>
<tbody>
<tr>
<td>interaction name</td>
<td>manifest names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Speak to</th>
</tr>
</thead>
<tbody>
<tr>
<td>interaction name</td>
<td>speak names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interaction</th>
<th>Linked to</th>
</tr>
</thead>
<tbody>
<tr>
<td>interaction name</td>
<td>linked names</td>
</tr>
</tbody>
</table>
From Architectural Design to Detailed Design I

- **Mapping Tables**
  - **Mapping Agent-Role table** ($MAR_t$) maps roles onto agents
  - **Mapping Society-Role table** ($MSR_t$) maps role onto society
  - **Mapping Artifact-Action table** ($MAAc_t$) maps actions onto individual artifacts
  - **Mapping Artifact-Resource table** ($MArR_t$) maps resources onto artifacts
  - **Mapping Aggregate-Resource table** ($MAggR_t$) maps resources onto aggregate
  - **Mapping Artifact-Operation table** ($MArOp_t$) maps operation onto environmental artifacts
  - **Mapping Artifact-Rule table** ($MArRu_t$) maps the rules specified in the Architectural Design onto the artifacts that implement and enforce them
  - **Mapping Artifact-Operation table** ($MSW_t$) maps spaces onto workspaces
From Architectural Design to Detailed Design II

- Mapping Interaction-Uses table ($MIU_t$) maps interactions onto uses
- Mapping Interaction-Manifests table ($MIM_t$) maps interactions onto manifests
- Mapping Interaction-SpeaksTo table ($MISp_t$) maps interactions onto speaks to
- Mapping Interaction-LinksTo table ($MIL_t$) maps interactions onto links to
Detailed Design: Tabular Representation

- Agent/Society Design Tables in top-down order – \((L)AA_t, (L)SA_t, (L)SA_{Art}\)

<table>
<thead>
<tr>
<th>Agent</th>
<th>(Individual) Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>agent name</td>
<td>artifact names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Society</th>
<th>Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Society name</td>
<td>agent names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Society</th>
<th>Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>society name</td>
<td>artifact names</td>
</tr>
</tbody>
</table>
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** ($(L)SA_r$) specifies the artifacts related to societies.
Detailed Design: Tabular Representation

- Environment Design Tables in top-down order – $AUI_t$, $AggArt_t$, $AggAge_t$

<table>
<thead>
<tr>
<th>Artifact</th>
<th>Usage Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>artifact name</td>
<td>list of operations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>aggregate name</td>
<td>artifact names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>aggregate name</td>
<td>agent names</td>
</tr>
</tbody>
</table>
Environment Design Tables

- **Artifact-UsageInterface Table** \((L)AUI_t\) specifies the operations provided by artifacts.
- **Aggregate-Artifact table** \(AggArt_t\) lists the artifacts belonging to a specific aggregate.
- **Aggregate-Agent table** \(AggAge_t\) lists the agents belonging to a specific aggregate.
## Detailed Design: Tabular Representation

- Interaction Design Tables in top-down order – $UP_t$, $UAge_t$, $SP_t$, $SpAge_t$, $MP_t$, $MArt_t$, $LP_t$, $LArt_t$

<table>
<thead>
<tr>
<th>Use</th>
<th>Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>uses name</td>
<td>protocol description</td>
</tr>
<tr>
<td>Agent</td>
<td>Use</td>
</tr>
<tr>
<td>agent name</td>
<td>uses names</td>
</tr>
<tr>
<td>Speak To</td>
<td>Protocol</td>
</tr>
<tr>
<td>speaks name</td>
<td>protocol description</td>
</tr>
<tr>
<td>Agent</td>
<td>Speaks To</td>
</tr>
<tr>
<td>agent name</td>
<td>speaks names</td>
</tr>
<tr>
<td>Manifests</td>
<td>Protocol</td>
</tr>
<tr>
<td>manifests name</td>
<td>protocol description</td>
</tr>
<tr>
<td>Artifact</td>
<td>Manifests</td>
</tr>
<tr>
<td>artifact name</td>
<td>manifests names</td>
</tr>
<tr>
<td>Links To</td>
<td>Protocol</td>
</tr>
<tr>
<td>links name</td>
<td>protocol description</td>
</tr>
<tr>
<td>Artifact</td>
<td>Links To</td>
</tr>
<tr>
<td>artifact name</td>
<td>links names</td>
</tr>
</tbody>
</table>
Detailed Design: Tabular Representation

- Interaction Design Tables concern the design of interactions among entities
  - *Use-Protocol table* ($UP_t$) details the protocols for each “uses interaction”
  - *Uses-Agent table* ($UAge_t$) specifies the “uses” where each agent is involved
  - *SpeaksTo-Protocol table* ($SP_t$) details the protocols for each “speaks to interaction”
  - *SpeaksTo-Agent table* ($SpAge_t$) specifies the “speaks to” where each agent is involved
  - *Manifests-Protocol table* ($MP_t$) details the protocols for each “manifests interaction”
  - *Manifests-Artifact table* ($MArt_t$) specifies the “manifests” where each artifact is involved
  - *LinksTo-Protocol table* ($LP_t$) details the protocols for each “links to” interaction
  - *LinksTo-Artifact table* ($LArt_t$) specifies the “links to” where each artifact is involved
### Detailed Design: Tabular Representation

- **Topological Design Tables in top-down order:** \((L)W_t,(L)WC_t,(L)WArt_t\) and \((L)WA_t\)

<table>
<thead>
<tr>
<th>Workspace</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>workspace name</td>
<td>description</td>
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</table>

<table>
<thead>
<tr>
<th>Workspace</th>
<th>Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>workspace name</td>
<td>workspace names</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workspace</th>
<th>Artifact</th>
</tr>
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<tbody>
<tr>
<td>workspace name</td>
<td>artifact names</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Agent</th>
<th>Workspace</th>
</tr>
</thead>
<tbody>
<tr>
<td>agent name</td>
<td>workspace names</td>
</tr>
</tbody>
</table>
Topological Design Tables describe the structure of the environment:

- *Workspace table* \((L)W_t\) describes the workspaces
- *Workspace-Connection table* \((L)WC_t\) shows the connections among the workspaces
- *Workspace-Artifact table* \((L)WArt_t\) shows the allocation of the artifacts to workspaces
- *Workspace-Agent table* \((L)WA_t\) lists the workspaces that each agent can perceive
SODA allows engineers to
- design societies
- design environments
- support the complexity of system description (layering principle)

Future works
- testing SODA
- refining the meta-model
- building the tools
- extracting fragments from SODA according to IEEE-FIPA Method Engineering
- integration between methodologies’ and infrastructures’ processes
Web Site

http://soda.apice.unibo.it
Available Theses & Projects

On the web site

- Kit&SODA: A Toolkit for SODA
- Graph&SODA: A Graphical Tool for SODA
- Check&SODA: A Consistency Checker for SODA
- Testing of SODA in different case studies
A study of some multi-agent meta-models. 

Process models for agent-based development. 
Engineering Applications of Artificial Intelligence, 18(2):205–222.

Software process: a roadmap. 
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The SODA AOSE Methodology
Multiagent Systems LS
Sistemi Multiagente LS

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