



UNIVERSIDAD DE SEVILLA
Escuela Técnica Superior
de Ingeniería Informática
Departamento de Lenguajes
y Sistemas Informáticos

Static Modeling

Class & Object Diagrams

Software Engineering and Databases Group
Department of Computer Languages and Systems
University of Seville
November 2015

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Static Modeling: Class & Object Diagrams

- Learning objectives
 - Know the basic concepts of **static modeling** using **UML class & object diagrams**.
 - Be able to **develop** a static model of a software system from a requirements specification.

1. Static model of a softw. system

2. Basic concepts

- Entity class
- Association
- Objects & links

3. Advanced concepts

- Composition & aggregation
- Generalization & especializat.
- Association class
- Constraints
- Derived elements
- Enumerations

4. Static model development



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Static Modeling: Class & Object Diagrams

- A model of a software system includes...
 - A **static model** (conceptual model)
 - Describes the structure and constraints of the information representing the system state.
 - A **behavior model**
 - Describes how the system interacts with actors and how its state evolves as a result of the interactions.

Model =

Static model = {
Structure
+
Constraints

+

Behavior model = {
External interactions
+
Internal evolution

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Static Modeling: Class & Object Diagrams

- A model of a software system includes...
 - Structure**
 - It describes the **information structure** representing the system state using...
 - UML class diagrams
 - UML object diagrams (scenarios)
 - Constraints**
 - They describe which system states are **valid** and which are not using...
 - UML class diagrams (multiplicities)
 - Constraints associated to UML class diagrams elements, expressed either in natural language or in **OCL** (Object Constraint Language).

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Static Modeling: Class & Object Diagrams

Requirements traceability

All the elements in a static model must be **traced** back towards those requirements that justifies them, usually **information requirements** and **business rules**.

class Ejemplo trazabilidad

RI-001 - El sistema deberá almacenar la información correspondiente a los usuarios del sistema. En concreto: ...

RF-004 - El sistema deberá enviar automáticamente un email a los usuarios cuando ...

«entidad» Usuario

nombre
apellidos
fechaNacimiento
email

«trace»

«trace»

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Modelado Estático: Diagramas de Clases y Objetos

Requirements traceability

All the elements of a static model must be **traced** back towards those requirements that justifies them, usually **information requirements** and **business rules**.

REM 1.3 Beta (MSXML 4) - [Aceites Guadalimar.rem]

6 Matrices de rastreabilidad

TRM:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	OBJ:	
0003	0001	0002	0003	0004	0005	0007	0008	0009	0010	0011	0012	0013
IRQ:	-	-	-	↑	-	↑	-	-	-	-	-	-
0001	-	-	-	-	↑	-	-	-	-	-	-	-
0002	-	-	-	-	-	-	-	-	-	-	-	-
IRQ:	↑	-	-	-	-	-	-	-	-	-	-	-
0003	-	-	-	-	-	-	-	-	-	-	-	-
0004	↑	-	-	-	-	-	-	-	-	-	-	-
IRQ:	-	-	-	-	-	↑	-	-	-	-	-	-
0005	-	-	-	-	-	-	-	-	-	-	-	-
IRQ:	-	-	-	-	-	-	-	-	-	-	-	-
0009	-	-	-	-	-	-	-	-	-	-	-	-
IRQ:	-	-	-	-	-	-	-	-	-	-	↑	-

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1. Static model of a softw. system

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4. Static model development

• Entity class

• Association

• Objects & links

• Composition & aggregation

• Generalization & especializat.

• Association class

• Constraints

• Derived elements

• Enumerations

Static Modeling: Class & Object Diagrams

• Basic concepts of static modeling

– Entity class

• Attribute

– Association

• Role

• Multiplicity

– Association class

– Object (instance of a class)

– Link (instance of an association)

– Generalization and specialization

– Composition and aggregation

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1. Static model of a softw. system

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• Entity class

– It represents a **relevant concept** from the problem domain for which the system must store information...

• ...because it is specified in (or deduced from) some requirements.

– Classes are named with a **noun in singular form**.

class Ejemplos de clases

«entidad»
Alumno

nombre
fechaNacimiento
...

«entidad»
Asignatura

código
nombre
...

«entidad»
Matrícula

número
fecha
tieneBeca
...

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4. Static model development

Static Modeling: Class & Object Diagrams

- Entity class attributes
 - They are **properties** of a relevant concept from the problem domain that the system must store...
 - ...because it is specified in (or deduced from) some requirements (traces*).
 - They are named with a **noun in singular form** and their values must be simple (not data structures).
 - They can be optional ([0..1]).

class Ejemplos de clases

«entidad»
Alumno

nombre
fechaNacimiento
...

«entidad»
Asignatura

código
nombre
...

«entidad»
Matrícula

número
fecha
tieneBeca
...

* Usually, traces are set at a class level, although they could also be set at an attribute level.

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Static Modeling: Class & Object Diagrams

- Association between entity classes
 - It represents some kind of **relationship** between two or more relevant concepts from the problem domain that the system must be aware of...
 - ...because it is specified in (or deduced from) some requirements.

class Ejemplos de asociación

«entidad»
Asignatura

código
nombre
...

apareceEn

«entidad»
Matrícula

número
fecha
tieneBeca
...

0..*

0..*

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Static Modeling: Class & Object Diagrams

- Association between entity classes
 - It is named using a **verb** in **singular third person** and prepositions if needed.
 - It must form a **comprehensible sentence** when reading it together with the roles.

class Ejemplos de asociación

«entidad»
Asignatura
código
nombre
...

apareceEn

«entidad»
Matrícula
número
fecha
tieneBeca
...

0..*

0..*

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4. Static model development

Static Modeling: Class & Object Diagrams

- Role of an association end
 - Role** played by each of the classes participating in an association.
 - By default, it is its own name starting in lower case.
 - They **must** be specified in:
 - Associations of a class with itself
 - When there exist more than one association between the same two classes.

class Ejemplos de roles

esPadreDe ▶

padre 0..2

Persona

hijo 0..*

Vuelo

salida *
llegada *

saleDe 1
llegaA 1

origen 1
destino 1

Aeropuerto

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4. Static model development

class Ejemplo asociación

«entidad»
Asignatura
código
nombre
...

apareceEn

«entidad»
Matrícula
número
fecha
tieneBeca
...

0..*0..*

class Ejemplos de roles

padre
0..2

Persona

esPadreDe

hijo
0..*

Vuelo

salida
*

saleDe

origen
1

Aeropuerto

llegada
*

llegaA

destino
1

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4. Static model development

class Ejemplo asociación

«entidad»
Asignatura
código
nombre
...

apareceEn

«entidad»
Matrícula
número
fecha
tieneBeca
...

0..*0..*

class Ejemplos de roles

padre
0..2

Persona

esPadreDe

hijo
0..*

Vuelo

salida
*

saleDe

origen
1

Aeropuerto

llegada
*

llegaA

destino
1

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4. Static model development

Static Modeling: Class & Object Diagrams

- Constraints at an association end
 - {nonunique}**: duplicates are allowed
 - {ordered}**: objects are ordered
 - By default, it assumed that duplicates are not allowed and that object are unordered.

	unordered	{ordered}
without duplicates	Set (default)	Ordered set
with duplicates {nonunique}	Bag	Sequence

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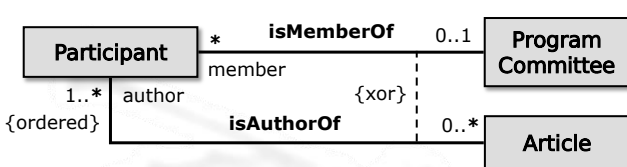
3. Advanced concepts

- Composition & aggregation
- Generalization & especializat.
- Association class
- Constraints
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- Enumerations

4. Static model development

Static Modeling: Class & Object Diagrams

- Constraints between associations
 - {xor}**: it indicates that the objects of the class common to the constrained associations cannot have links of more than one association.
 - Example: a participant in a conference cannot be an author of an article and, at the same time, member of the program committee.



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4. Static model development

Static Modeling: Class & Object Diagrams

• Objects

- Every **instance** or occurrence of a class.

• Links

- Every **instance** or occurrence of an association.

class Equipos de fútbol

«entidad»
Jugador
nombre

juegaEn

«entidad»
Equipo
nombre
...

0..1

*

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Static Modeling: Class & Object Diagrams

• Objects

- Every **instance** or occurrence of a class.

• Links

- Every **instance** or occurrence of an association.

object Equipos de fútbol

j1 : Jugador
nombre = "Antoñito"

juegaEn

e2 : Equipo
nombre = "Xerez CD"

juegaEn

j3 : Jugador
nombre = "Kanouté"

j2 : Jugador
nombre = "Redondo"

juegaEn

e1 : Equipo
nombre = "Sevilla FC"

juegaEn

j4 : Jugador
nombre = "Negredo"

j6 : Jugador
nombre = "Luis Fabiano"

juegaEn

j5 : Jugador
nombre = "Jesús Navas"

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Static Modeling: Class & Object Diagrams

- Extension of a class
 - All the instances of a given class in the system.

Class "Jugador" extension

Class "Equipo" extension

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Static Modeling: Class & Object Diagrams

- Composition
 - Special association that represents the concept of **being-part-of** or **being-composed-of**:
 - A *part* (component) only belongs to one *whole* (composite).
 - A *part* cannot exists without being part of one *whole*.
 - The elimination of the *whole* implies the elimination of all its *parts*.
 - It is a transitive and antisymmetric relation.
 - It can be recursive.

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Static Modeling: Class & Object Diagrams

• Aggregation

- Weak composition in which:
 - A *part* (component) can belong to more than on *whole* (aggregate), i.e. its multiplicity is not constrained to be 1.
 - A *part* can exist without belonging to a *whole*.
 - The elimination of the *whole* does not necessarily implies the elimination of all its *parts*.

class Ejemplos de agregación

Polígono

Punto

3..* {ordered}

Grupo musical

Músico

1..*

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Static Modeling: Class & Object Diagrams

• Generalization/Specialization

- Sometimes, some concepts from the problem domain have relationships of type **is-a**, for example:

car

vehicle

motorcycle

truck

is-a

is-a

is-a
- These concepts usually have **common properties**, that appears as attributes or common associations when they are modeled.

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Static Modeling: Class & Object Diagrams

• Generalization/Specialization

class Ejemplo de generalización

```
classDiagram
    class Persona {
        +matrícula
        +númeroBastidor
        +modelo
        +plazas
    }
    class Automóvil {
        +matrícula
        +númeroBastidor
        +modelo
        +plazas
    }
    class Camión {
        +matrícula
        +númeroBastidor
        +modelo
        +tonelaje
        +ejes
    }
    class Motocicleta {
        +matrícula
        +númeroBastidor
        +modelo
        +cilindrada
    }
    class Seguro {
        +compañía
        +númeroPóliza
        +tipo
        +precio
    }
    class Seguros {
        +compañía
        +númeroPóliza
        +tipo
        +precio
    }

    Persona "0..1" -- "*" Automóvil : esPropietarioDe
    Persona "0..1" -- "*" Camión : esPropietarioDe
    Persona "0..1" -- "*" Motocicleta : esPropietarioDe
    Automóvil "1" -- "0..1" Seguro : asegurado
    Camión "1" -- "0..1" Seguro : asegurado
    Motocicleta "1" -- "0..1" Seguro : asegurado
    Seguro "0..1" -- "0..1" Seguros : tieneSeguro
```

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Static Modeling: Class & Object Diagrams

• Generalization/Specialization

class Ejemplo de generalización

```
classDiagram
    class Persona {
        +matrícula
        +númeroBastidor
        +modelo
        +plazas
    }
    class Seguro {
        +compañía
        +númeroPóliza
        +tipo
        +precio
    }
    class Vehículo {
        +matrícula
        +númeroBastidor
        +modelo
    }
    class Automóvil {
        +plazas
    }
    class Motocicleta {
        +cilindrada
    }
    class Camión {
        +tonelaje
        +ejes
    }

    Persona "0..1" -- "*" Vehículo : esPropietarioDe
    Seguro "0..1" -- "1" Vehículo : asegurado
    Vehículo <|-- Automóvil
    Vehículo <|-- Motocicleta
    Vehículo <|-- Camión
    Vehículo -- "1" Seguros : tieneSeguro
```

– The most general class (the **superclass**), contains all the common properties (attributes and associations), **inherited** by the specific classes (**subclasses**).

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Static Modeling: Class & Object Diagrams

• Generalization/Specialization

class Ejemplo de generalización

Generalization

Specialization

- All the instances of the subclasses are also instances of the superclass.
- Generalization is a transitive and antisymmetric relation.

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Static Modeling: Class & Object Diagrams

• Generalization/Specialization

class Ejemplo de generalización

Abstract class

The name of
abstract classes
is written in italics.

- {complete, disjoint} implies a **partition** of the set of instances of the superclass.

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Static Modeling: Class & Object Diagrams

• Generalization/Specialization

class Ejemplo comunidad universitaria

```
classDiagram
    class MiembroCU
    class Alumno
    class Empleado
    class PAS
    class PDI
    MiembroCU <|-- Alumno
    MiembroCU <|-- Empleado
    Empleado <|-- PAS
    Empleado <|-- PDI
    Alumno --|> Empleado : {completa, solapada}
    Empleado --|> PAS : {completa, disjunta}
    Empleado --|> PDI : {completa, disjunta}
```

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- Entity class
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4. Static model development

Static Modeling: Class & Object Diagrams

• Association class

– Sometimes, some information must be added to associations, turning them into classes.

```
classDiagram
    class Employee
    class Project
    class Effort
    Employee "*" -- "*" Project : works in
    class Effort {
        hours
    }
    Effort -- Employee
    Effort -- Project
```

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Static Modeling: Class & Object Diagrams

- Association class
 - Example: the hours that an employee works on a project are neither properties of the employee nor the project, but of the association between them.

```
graph LR
    e1[e1: Employee] -- worksIn --- p1[p1: Project]
    e1 -- worksIn --- p2[p2: Project]
    e2[e2: Employee] -- worksIn --- p1
    e2 -- worksIn --- p2
    e3[e3: Employee] -- worksIn --- p2
    f1[f1: Effort hours = 20] -.- e1
    f1 -.- p1
    f2[f2: Effort hours = 15] -.- e1
    f2 -.- p2
    f3[f3: Effort hours = 7,5] -.- e2
    f3 -.- p1
    f4[f4: Effort hours = 25] -.- e3
    f4 -.- p2
    f5[f5: Effort hours = 12] -.- e2
    f5 -.- p2
```

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Introduction to Conceptual Modeling

- Association class
 - It is also possible to model them as a class component of the participating classes.
 - Both models are equivalent.

```
classDiagram
    class Empleado {
        nombre
    }
    class Proyecto {
        nombre
        presupuesto
    }
    class Esfuerzo {
        horas
    }
    Empleado "1" -- "*" Proyecto : trabajaEn
    classDiagram
    class Empleado {
        nombre
    }
    class Proyecto {
        nombre
        presupuesto
    }
    class Esfuerzo {
        horas
    }
    Empleado "1" *-- "*" Esfuerzo
    Proyecto "1" *-- "*" Esfuerzo
```

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Static Modeling: Class & Object Diagrams

• Constraints

– They allow additional information in the model which cannot be expressed in any other way.

class Ejemplo de restricción

Notation

Constraints are represented as **notes**. The text must be between curly braces, indicating the name of the constraint and its description. Optionally, it can be linked to the affected entities.

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Static Modeling: Class & Object Diagrams

• Derived elements

– The slash (/) indicates that some attribute or association can be **derived** (computed).

– **Constraints** describing derivations must be added to the model.

class Ejemplo de derivados

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Static Modeling: Class & Object Diagrams

- Notation for enumerations
 - They define a **type** that can be used in class attributes.
 - The attributes of the enumerations are the possible values.

class Notación enumerados

«enumerado»
Sexo

hombre
mujer

«enumerado»
VíaPública

calle
plaza
avenida
carretera

«enumerado»
Categoría

infantil
aventuras
cienciaFicción
drama

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Static Modeling: Class & Object Diagrams

- Conceptual model development
 - Recommended steps:
 1. Analyze the information about the problem domain (glossary) and requirements.
 2. Identify possible entities and attributes.
 3. Identify possible associations.
 4. Incrementally build the conceptual model identifying the multiplicity of the associations.
 5. Identify classifications between entities with common properties (attributes and/or associations).
 6. Identify composition between entities.
 7. Add the constraints that cannot be graphically expressed.
 8. Validate with possible scenarios using object diagrams.
 9. Register all semantic problems that must be discussed with customers and users.

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Static Modeling: Class & Object Diagrams

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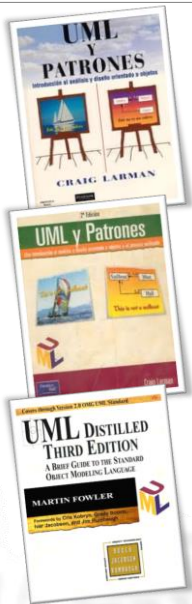
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Static Modeling: Class & Object Diagrams

• Comments, suggestions, ...



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