Model-Driven Software Engineering (MDSE)

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What is a Meta-metamodel?

- A metamodel describes information about models
- A meta-metamodel describes information about metamodels
- Metamodels that are defined using the same meta-metamodel
  - Can exchange information
  - Can be used by the same CASE tools that understand the meta-metamodel

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What is MOF?

- MOF stands for Meta Object Facility
  - enables meta-metamodeling of UML level metamodels
- It defines a small set of concepts (such as package, class, method, attribute…) that
  - allow one to define and manipulate **models** of metadata (data about data)
  - are described using a subset UML notation

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OMG 4-Layer Architecture

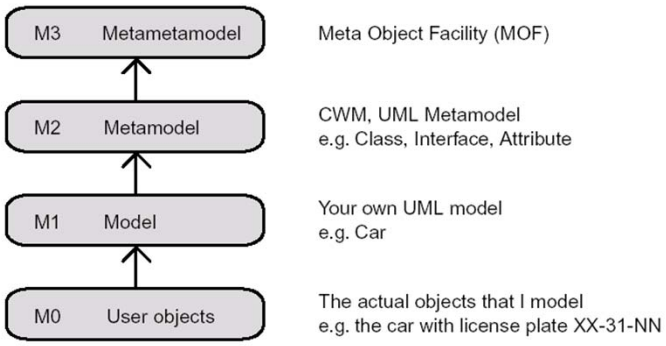

Figure 1 *OMG 4-layer architecture*

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MOF Key Abstract Classes (Cont.)

- **ModelElement** common base Class of all M3-level Classes. Every ModelElement has a name
- **Namespace** base Class for all M3-level Classes that need to act as containers
- **GeneralizableElement** base Class for all M3-level Classes that support generalization (i.e. inheritance)
- **TypedElement** base Class for M3-level Classes such as Attribute, Parameter, and Constant whose definition requires a type specification
- **Classifier** base Class for all M3-level Classes that (notionally) define types. Examples of Classifier include Class and DataType

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The MOF Model: Main Concrete Classes

- The key concrete classes (or meta-metaclasses) of MOF are as follows:
  - Class
  - Association
  - Exception (for defining abnormal behaviours)
  - Attribute
  - Constant
  - Constraint

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The MOF Model: Key associations

- Contains: relates a ModelElement to the Namespace that contains it
- Generalizes: relates a GeneralizableElement to its ancestors (superclass and subclass)
- IsOfType: relates a TypedElement to the Classifier that defines its type
  - An object is an instance of a class
- DependsOn : relates a ModelElement to others that its definition depends on
  - E.g. a package depends on another package

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The UML Metamodel

- A UML model is an instance of the UML metamodel
- The UML metamodel
  - Describes the UML model elements
  - Is defined using a subset of UML
  - Is organized in the form of packages

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UML Metamodel (cont.)

- UML metamodel is based on MOF
- Every model element in UML metamodel maps to an element in MOF
- There is a metamodel to every UML diagram:
  - class diagrams
  - use case diagrams
  - etc.
- UML extension mechanisms have also a metamodel that defines them

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The UML Metamodel (cont.)

- UML metamodel is defined according to the following concepts:
  - Abstract Syntax: The metamodel of UML is described using UML class diagrams
  - Well-formedness rules: Well-formedness rules are used to express constraints on the model elements
    -E.g. a class cannot have two names
  - Semantics: describes using the natural language the semantics of the model elements

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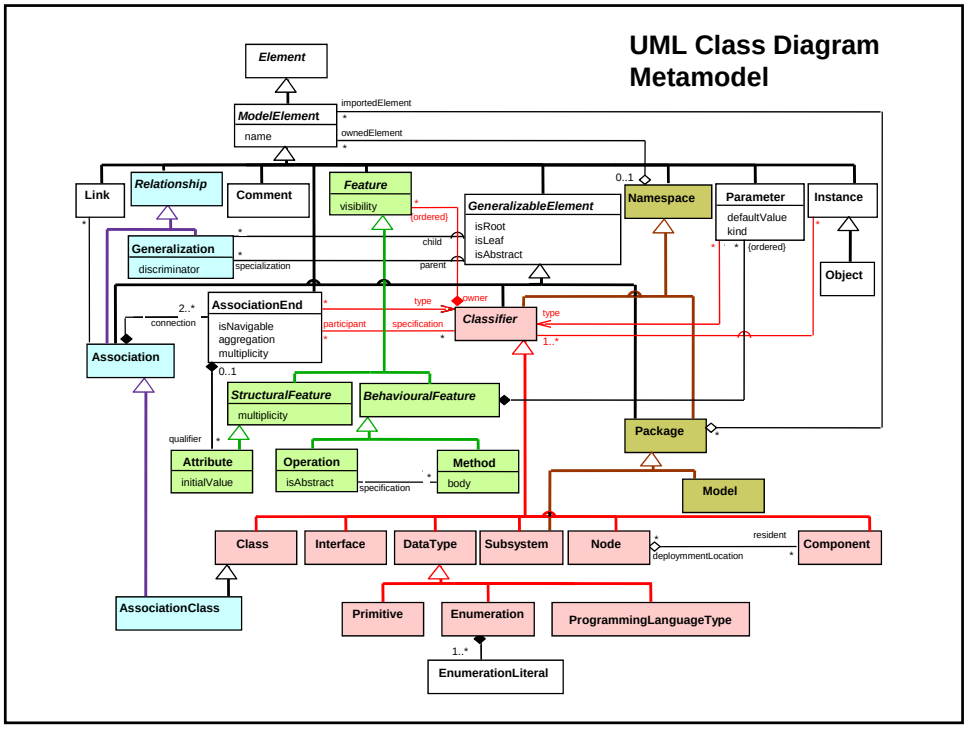
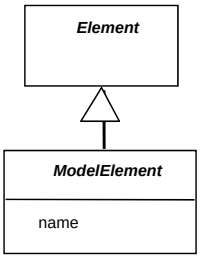


Model Elements

- An element is an atomic constituent of a model.
- Element is the top metaclass in the metaclass hierarchy
- A model element is a named entity in a Model
- It is the base for all modeling metaclasses in UML
  - All other modeling metaclasses are either direct or indirect subclasses of ModelElement



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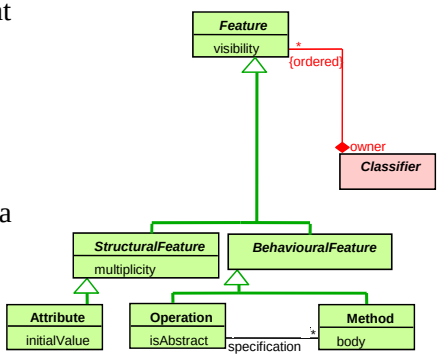
Features

- Feature is an abstract class that declares a behavioral or structural property of
  - an instance of a Classifier
  - the Classifier itself
- A behavioral feature refers to a dynamic feature of a model element
  - E.g. operation or method
- A structural feature refers to a static feature of a model element
  - E.g. attribute



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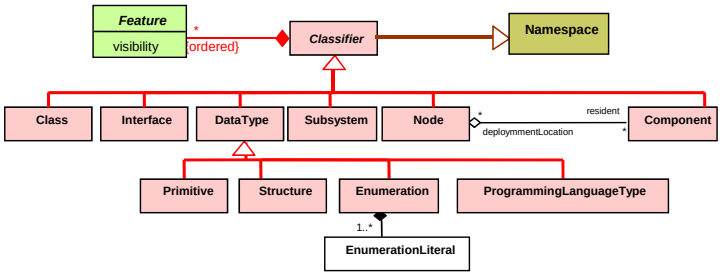
Classifier

- A classifier is an element that describes behavioral and structural features
  - E.g. class, data type, interface, component
- Classifier is an abstract class that
  - declares a collection of Features, such as Attributes, Methods…
  - has a name, which is unique in the Namespace enclosing the Classifier



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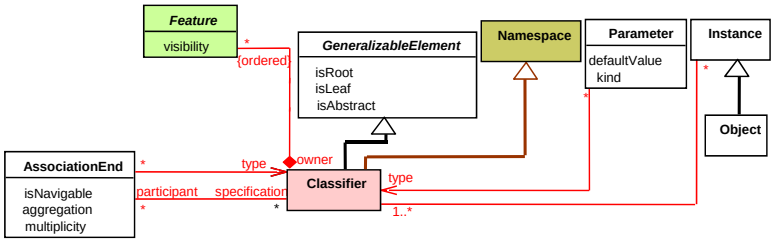
Classifier (cont.)

- A classifier defines a namespace and is a generalizable element
- Can have
  - association ends
  - parameters
  - instances



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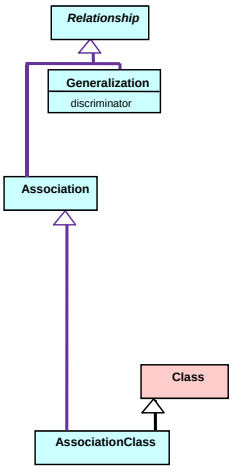
Relationships

- A relationship is a connection among model elements
- UML defines several relationships such as:
  - Association
  - Generalization
- UML defines other types of relationships that are not shown in this diagram, such as:
  - Dependency
  - Flow



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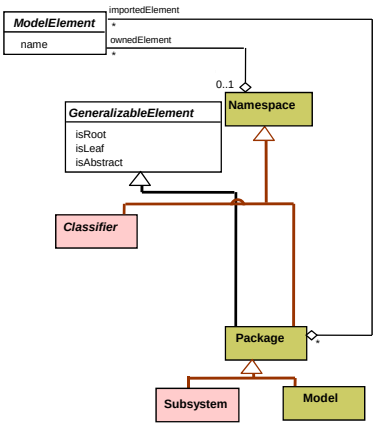
Namespace

- A namespace is a part of a model that contains a set of other model elements
  - E.g. Associations and Classifiers
  - the name of an owned model element is unique within the namespace
- Namespace is an abstract metaclass and it subclasses are
  - Classifier
  - Package



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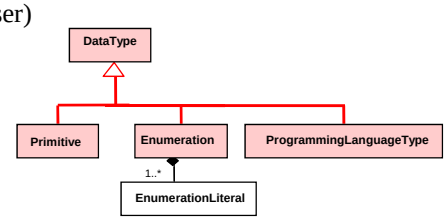
Data Types

- UML Data types include
  - primitive built-in types (such as integer and string)
  - definable enumeration types (such as Boolean whose literals are false and true)
- Programming languages data types
  - are specified according to the semantics of a particular programming language
  - are not portable among languages (except by agreement among the languages)
  - do not map into other UML classifiers
- Enumerations are a user-defined data types whose instances are literals (specified by the user)



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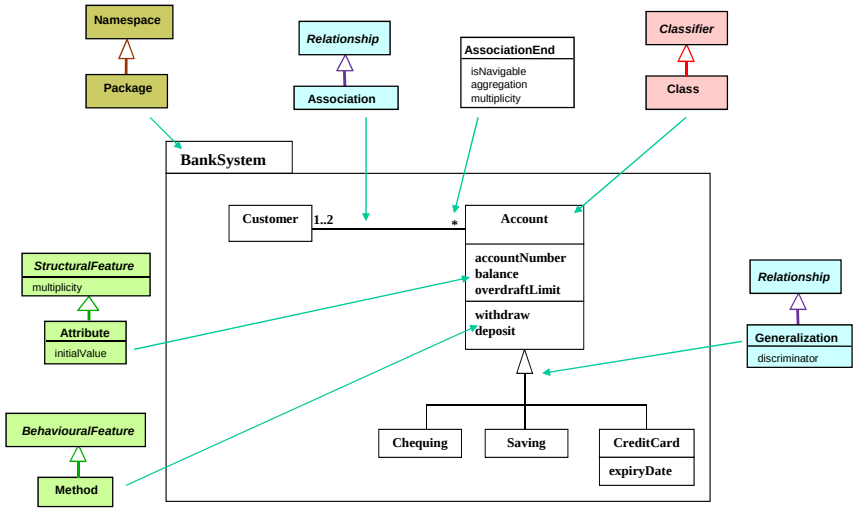

Mapping of UML Models to Metamodel Elements (Example)

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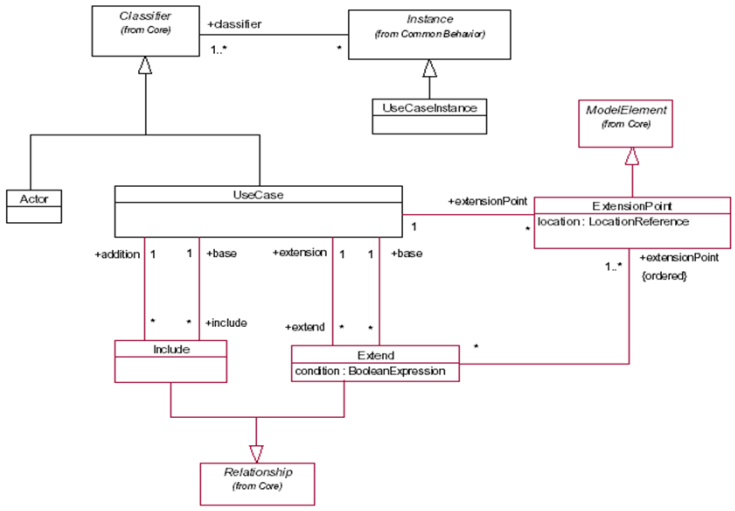
Use Case Diagrams Metamodel



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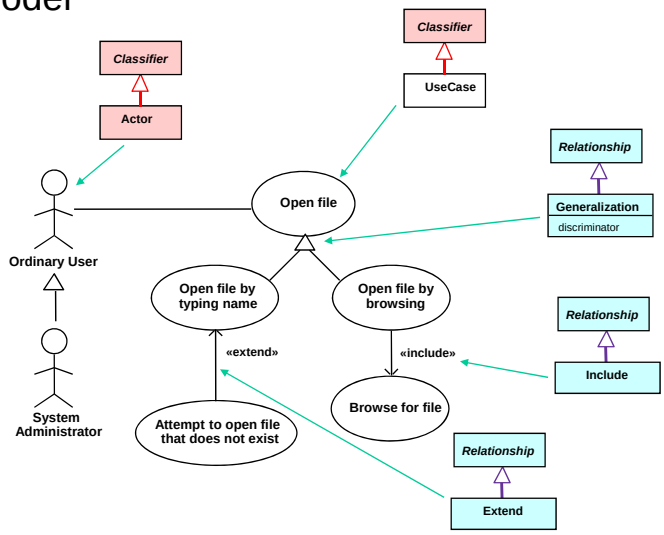
Mapping Use Cases Model to Metamodel



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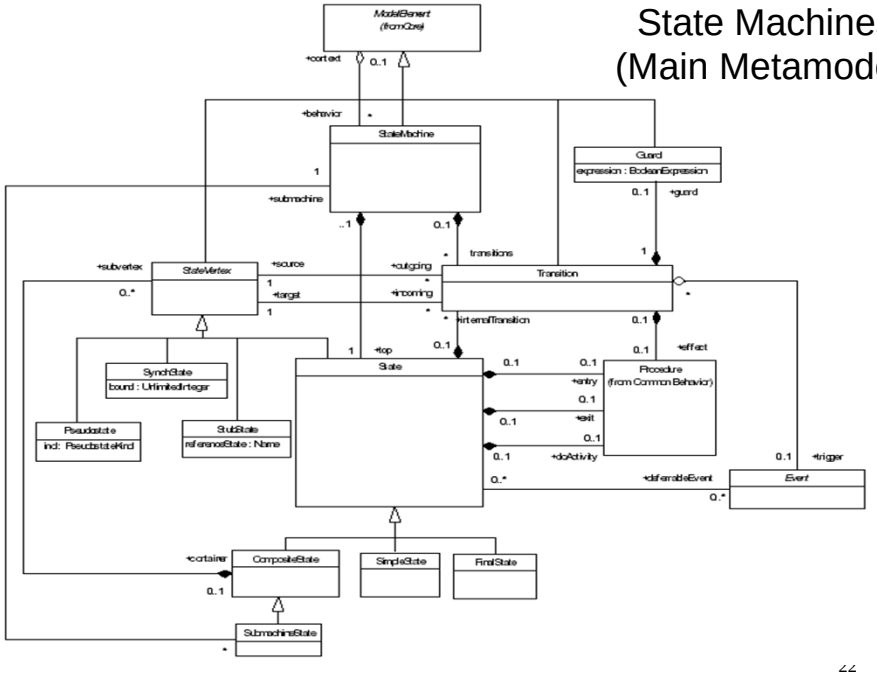
State Machines (Main Metamodel)



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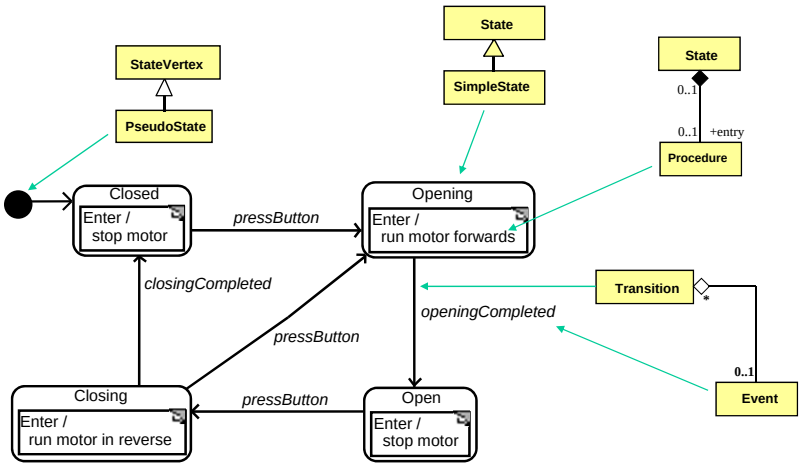
Mapping State Machines to Metamodel



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UML Extension Mechanisms

- Although UML is very well-defined, there are situations in which it needs to be customized to specific problem domains
- UML extension mechanisms are used to extend UML by:
  - adding new model elements,
  - creating new properties,
  - and specifying new semantics
- There are three extension mechanisms:
  - stereotypes, tagged values, constraints and notes

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Stereotypes

- Stereotypes are used to extend UML to create new model elements that can be used in specific domains
- E.g. when modeling an elevator control system, we may need to represent some classes, states etc. as
  - «hardware»
  - «software»
- Stereotypes should always be applied in a consistent way

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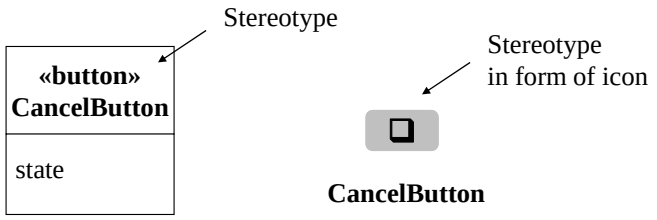
Stereotypes (cont.)

- Ways of representing a stereotype:
  - Place the name of the stereotype above the name of an existing UML element (if any)
    - The name of the stereotype needs to be between «» (e.g. «node»)
    - Don't use double '<' or '>' symbols, there are special characters called open and close guillemets
  - Create new icons



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Tagged Values

- Tagged values
  - Define additional properties for any kind of model elements
  - Can be defined for existing model elements and for stereotypes
  - Are shown as a tag-value pair where the tag represent the property and the value represent the value of the property
- Tagged values can be useful for adding properties about
  - code generation
  - version control
  - configuration management
  - authorship
  - etc.

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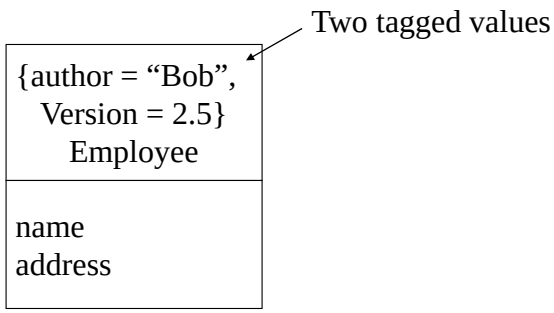
Tagged Values (cont.)

- A tagged value is shown as a string that is enclosed by brackets {} and which consists of:
  - the tag, a separator (the symbol =), and a value



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Constraints

- Constraints are used to extend the semantics of UML by adding new rules, or modifying existing ones.
- Constraints can also be used to specify conditions that must be held true at all times for the elements of a model.
- Constraints can be represented using the natural language or OCL

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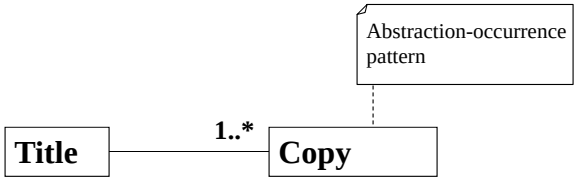
Comments

- Comments are used to help clarify the models that are being created
  - e.g. comments may be used for explaining the rationale behind some design decisions
- A comment is shown as a text string within a note icon.
- A note icon can also contain an OCL expression



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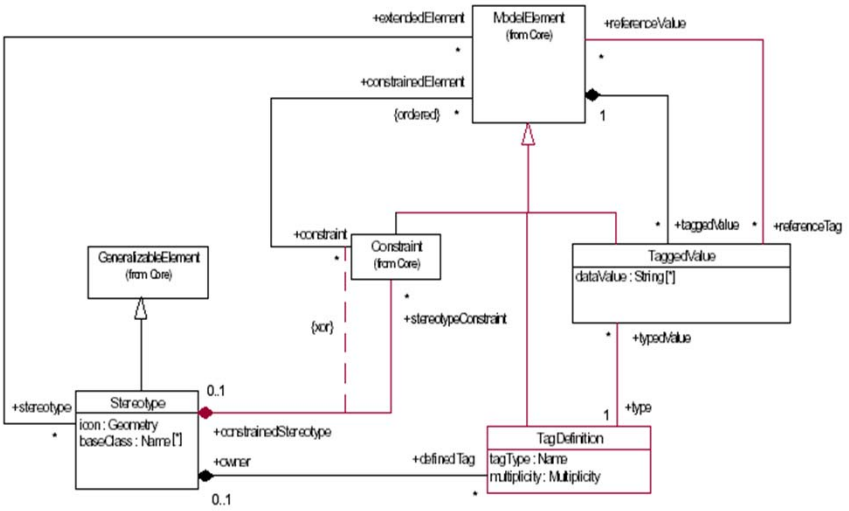
Extension Mechanisms Metamodel



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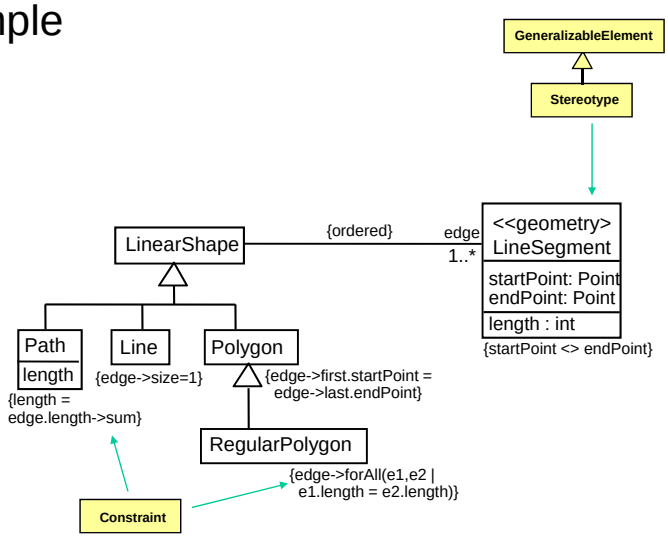
Example



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UML Profiles

- UML Profiles provide an extension mechanism for building UML models for particular domains
  - e.g. real-time systems, web development, etc…
- A profile consists of a package that contains one or more related extension mechanisms (such as stereotypes, tagged values and constraints)
  - that are applied to UML model elements
- Profiles do not extend the UML metamodel. They are also called *the UML light-weight extension mechanism*

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UML Profiles (cont.)

- A UML profile is a specification that does one or more of the following:
  - Identifies a subset of the UML metamodel (which may be the entire UML metamodel)
  - Specifies stereotypes and/or tagged values
  - Specifies well-formedness rules beyond those that already exist
  - Specifies semantics expressed in natural language
- We will cover UML profiles in the next class

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Example of a profile

inspired by the research report of Cabot et al. (2003)

- We would like to create a UML profile for representing basic GUI components.
- We suppose that our GUI contains the following components:
  - Forms (which can also be dialog boxes)
  - Buttons
- Constraints: (in practice, we need to be more precise)
  - A form can invoke a dialog box
  - A form as well as a dialog box can contain buttons

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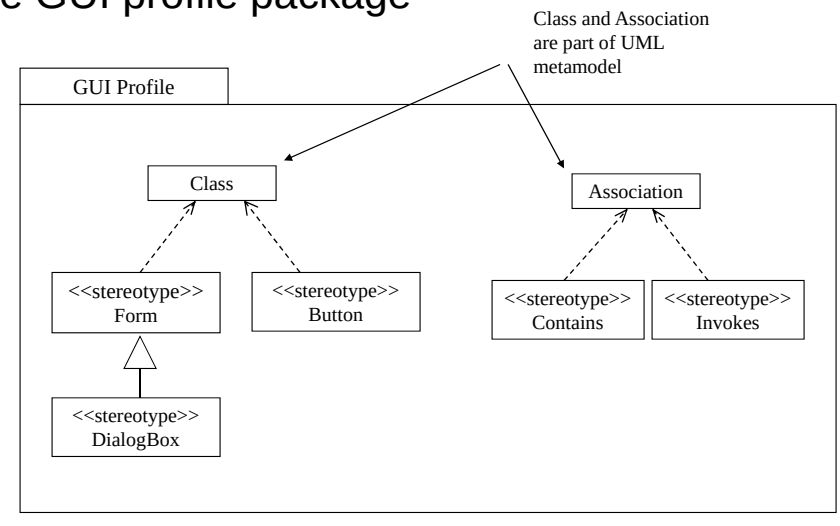
The GUI profile package



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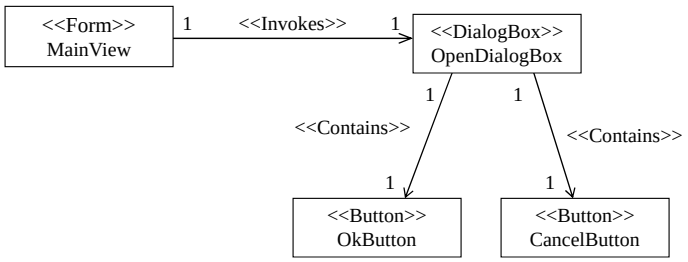
Instance Diagram of the GUI Profile



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