Model-Driven, Component Engineering

Colin Atkinson

2nd May 2007

University of St. Andrews

Agenda

- Components, Services and Models
- Model-Driven, Component-Based Development
- Orthographic Service Engineering

Components, Services and Models

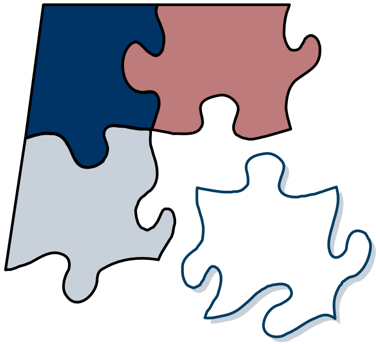
Contents

- Components
- Web services
- Models and MDA
- Design by contract

Motivation for Components

- the concept of systematic reuse in software is very attractive
  - increased reliability
    - components exercised in working systems
  - reduced process risk
    - less uncertainty in development costs
  - standards compliance
    - embed standards in reusable components
  - accelerated development
    - avoid original development and hence speed-up production

- promoted in software engineering in three main ways -
  - reusing knowledge and experience
    - patterns, standards, guidelines
  - developing generic solutions
    - product lines, frameworks
  - developing and assembling parts
    - component-based development

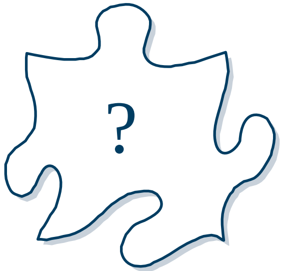


What is a Component?

- each author has his own favorite definition
  - " a component represents a modular, deployable, and replaceable **part of a system** that encapsulates implementation and exposes a set of interfaces "

    UML Specification
  - " a reusable software component is a logically cohesive, **loosely coupled module** that denotes a single abstraction "

    Booch 87
- frequently asked questions
  - does a component have state?
  - is a component an object?
  - is a component a module?



- most commonly accepted definition
  - " a software component is a unit of composition with contractually specified interfaces and context dependencies only. A software component can be deployed independently and is subject to composition by third parties "

    ECOOP'96

Software versus System Components

- key is to distinguish software and system components

Software Components

- functional elements of a software application at development time
- units of independent deployment
- units of third-party composition
- have no (externally) observable state
- define external context dependencies
- may be instantiatable

⇒ ***types, modules***

System Components

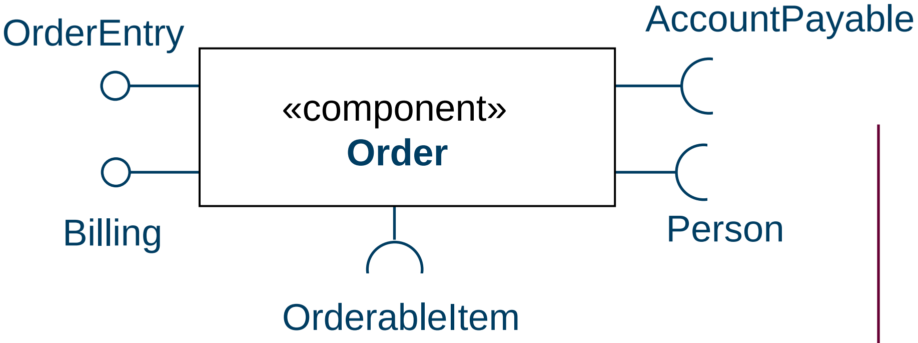
- functioning parts of a system in its execution environment
  - a.k.a Subsystem
- (semi)-autonomous parts of an executing system
- interact with system elements developed by third parties
- may have externally visible state
- have unique identity

⇒ ***objects, functions***

Key Characteristics of Components

- although components have some similarities to traditional classes and/or modules they have some important additional properties

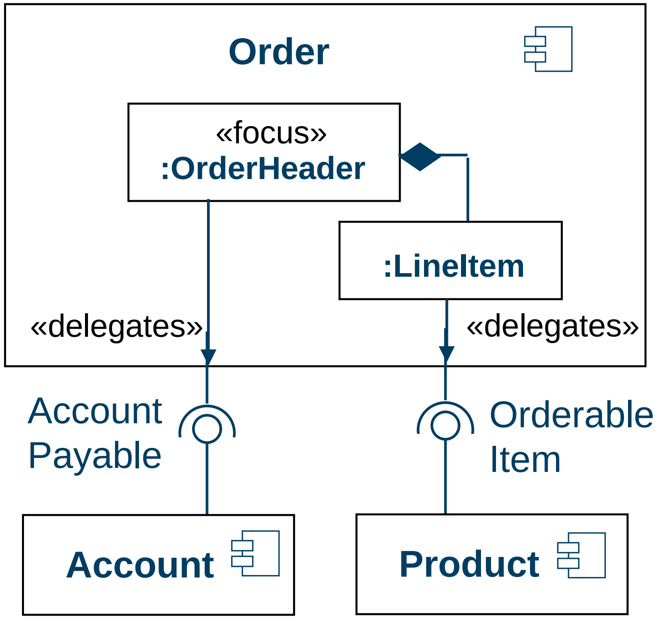
- they define “required” as well as “provided” interfaces
  - provided interface
    - services offered by the component
  - required interface
    - services required by the component



- they are self descriptive
  - accompanying meta-data describes relevant features of the component for potential users

Component Composition

- by definition components are assembled to create larger entities
  - ideally component assemblies have the same properties as primitive components and can be combined with into larger components
  - contemporary component technologies do not have this property
- components are assembled by using connectors
  - delegation connectors
    - link the external interface of a component to its internal realization via its parts
  - assembly connectors
    - indicate that one component provides the services that another component requires



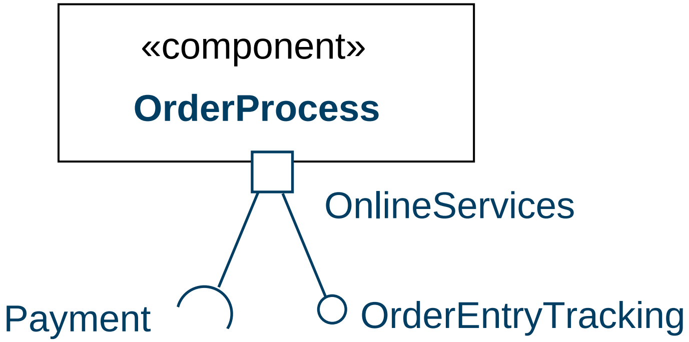
Ports

- a mechanism for isolating a classifier from its environment
  - provides a point for conducting interactions between the internals of the classifier and its environment

- allows a component to be defined independently of its environment
  - makes it reusable in any environment that conforms to the constraints imposed by its ports

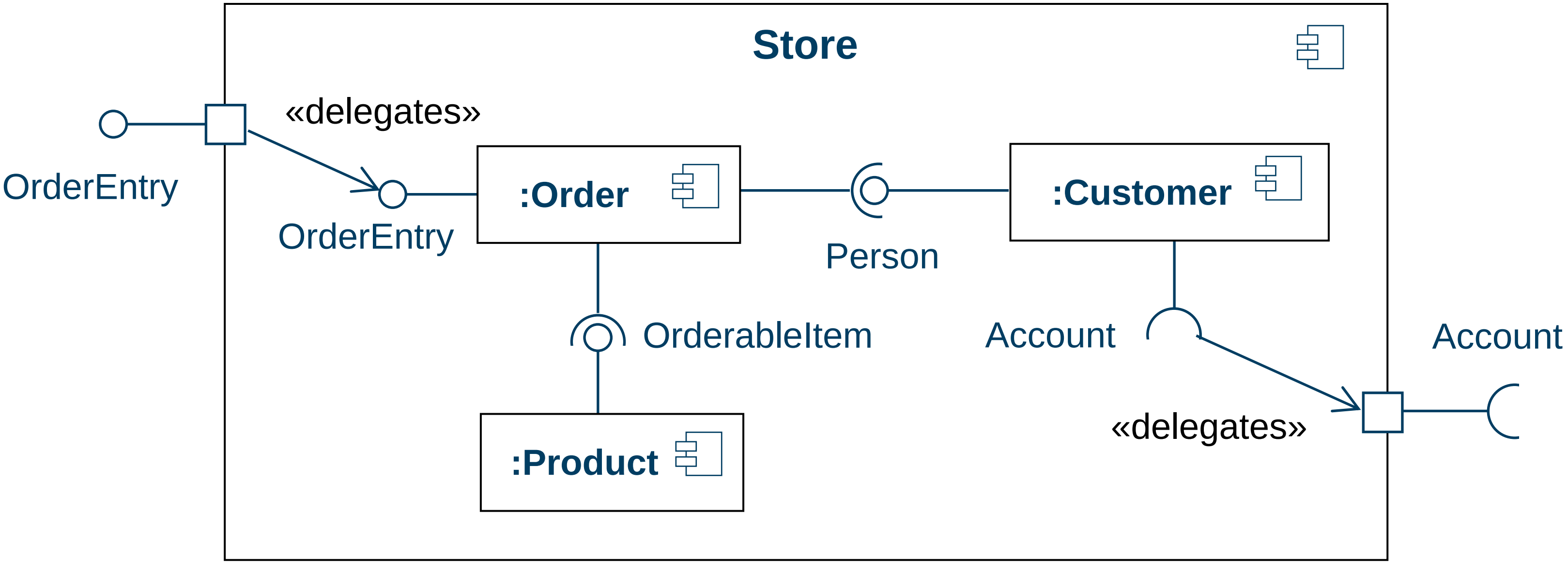
- required interfaces of a port describes requests which may be made from the component to its environment

- provided interfaces of a port characterize requests to the component from its environment



Logical Containment

- in recursive component models, one component can be nested or contained in another component to arbitrary depths
  - the composite component can be viewed as a (logical) container of its parts

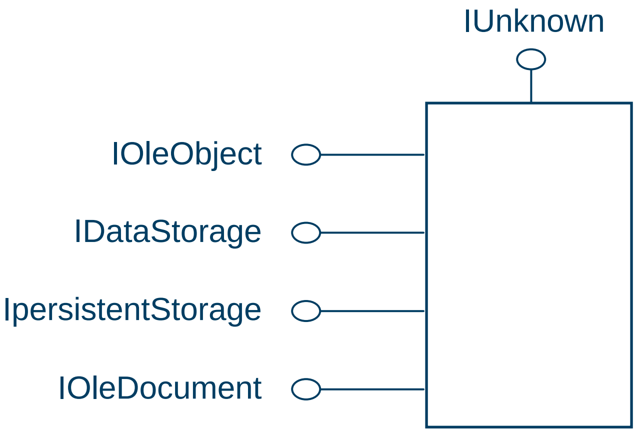


Component Description Levels

- Components can be realized at various abstraction levels
- language and platform independent
  - requires vendor-neutral interface specification language
  - tools translate vendor-neutral specifications to specific languages and/or platforms
  - main example – CORBA Component Model
- language specific, platform independent
  - requires a "write once, read everywhere" language
  - components must be written in that language
  - main example – Java component models
- language neutral, platform specific
  - language neutral binary specification
  - requires operating system to support the standard
  - main example – COM Component Models

Binary Component Models

- define how components are represented in memory
  - but not how programming languages are bound to them
- most well known is COM (Common Object Model)
  - foundation for all Microsoft component software
  - is widely available on other platforms also
  - is agnostic the use of objects to implement components
- QueryInterface Operation
  - takes a named interface and checks if the current COM object supports it
    - if so, it returns the corresponding interface reference
    - if not, it returns an error indication
  - allows a client with a reference to an interface to “get to” any other interface supported by the same COM object



Disadvantages of Component Based Development

- time and effort required for development of components
  - anecdotal evidence indicates that the effort invested in generalizing component is recovered after 5th reuse
- unclear and ambiguous requirements
  - reusable components are to be used in different applications, some of which may yet be unknown and the requirements of which cannot be predicted
- conflict between usability and reusability
  - to be widely reusable, a component must be sufficiently general, scalable and adaptable and therefore more complex
- component maintenance costs
  - while application maintenance costs can decrease, component maintenance costs can be very high

Motivation for Web Services

- distributed-object and component solutions have shortcomings
  - mainly for use within an intranet
  - a lot of interoperability problems due to their proprietary nature
  - do not scale to the Internet
  - tightly coupling services and consumers
  - server object implementations not portable
- to promote B2B interaction need an solution that
  - enables universal interoperability
  - enables widespread adoption
  - is based on ubiquitous open, extendible standards
  - requires minimal supporting infrastructure
  - focuses on messages and documents, not on APIs

What Are Web Services?

"Web services are a new breed of Web application. They are **self-contained**, **self-describing**, modular applications that can be **published**, **located**, and **invoked** across the Web. Web services perform functions, which can be anything from simple requests to complicated business processes. ...

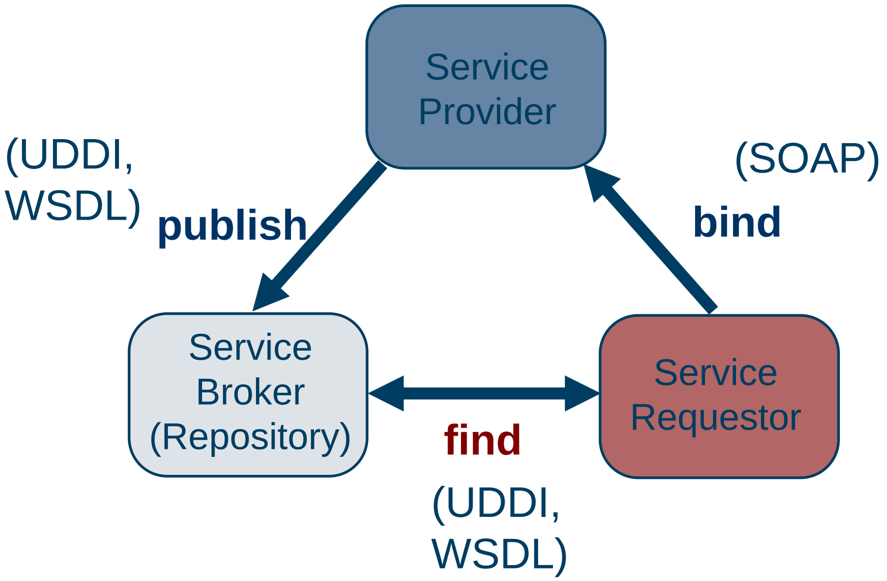
Once a Web service is deployed, other applications (and other Web services) can discover and invoke the deployed service."

IBM

- self-contained
  - functionality and attributes are exposed in a public interface while implementation is hidden
- self-describing
  - have a machine-readable description used to understand their interface
- modular
  - are reusable and can be composed to generate higher level functionality
- published
  - can be registered in electronic "yellow pages" for easy location by other applications
- located
  - are tied to a fixed, globally unique location identified through a URI
- invoked
  - can be invoked using an standard Internet protocol

Web Services Architecture

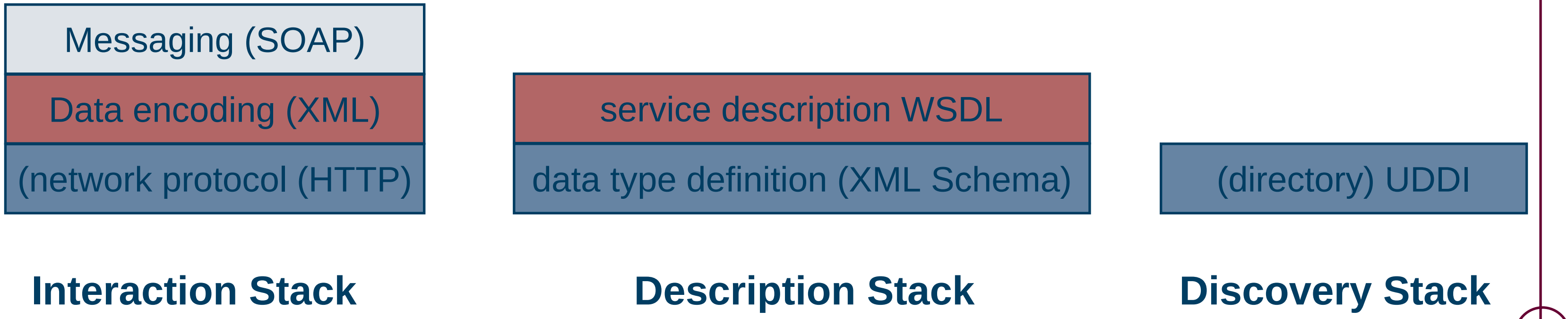
- elements in a system built from web services play one of three roles
  - service requestor
  - Service provider
  - Service broker (repository)



- service providers **publish** services by advertising service descriptions in the registry
- service requestors use **find** operation to retrieve service descriptions from the service registry
- service requestors **bind** to service providers using binding information found in service descriptions to locate and invoke a service

Core Web Service Technologies

- **SOAP** (Simple Object Access Protocol)
  - a message layout specification defining a uniform way of passing XML-encoded data
  - a way to simulate RPC over standard Web communication protocols
- **WSDL** (Web Service Description Language)
  - defines Web Services as collections of network endpoints or *ports*
  - a port is defined by associating a network address with a binding
- **UDDI** (Universal Description, Discovery and Integration)
  - provides a mechanism for clients to find web services
  - the basis for repository services for business applications



Messaging (SOAP)

Data encoding (XML)

(network protocol (HTTP)

service description WSDL

data type definition (XML Schema)

(directory) UDDI

Interaction Stack

Description Stack

Discovery Stack

Important Dichotomies

- Web Services versus Web Service providers
  - the term “service” is sometimes used to refer to just the abstract interface and sometimes to an implementing object
  - the terms “service interface” and “service provider” should be used when clarity is needed

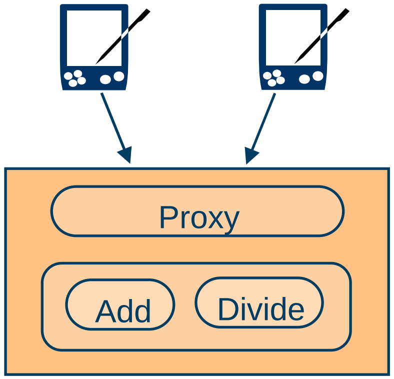
- Web Service types versus Web Service instances
  - strictly speaking Web Services are instances
  - WSDL specifications bind operations to specific URL’s as part of the definition of ports, and thus have a unique instance identity
  - however, SOAP specifications define an abstract interaction protocol (interface) which can be used with any conformant service provider

- Web Services versus components
  - Web services are not software components
  - they are instances, can have state, do not define required interfaces ..
  - but they are clearly system components

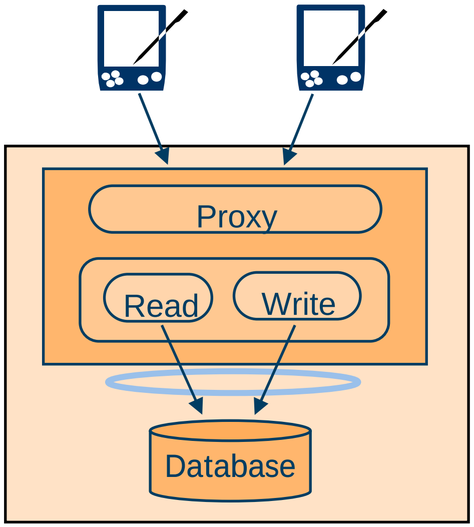
⇒ Web Services are objects !

Are Web Services Stateless or Stateful?

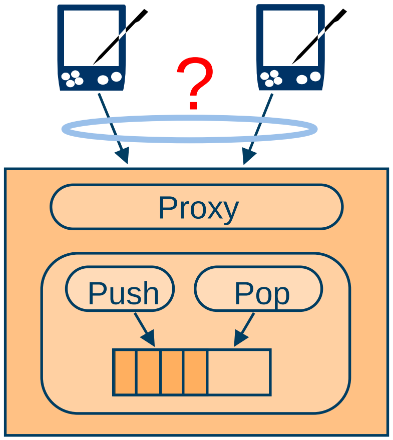
- the core Web Service standards allow Web Services to be stateful since one web service can export multiple methods
- however, they are often characterized as stateless because
  - the core standards have no mechanism for controlling concurrent access to web services in a multi-client environment
  - the “state” of stateful web service abstractions is usually stored outside the service provider code



Stateless Web Service

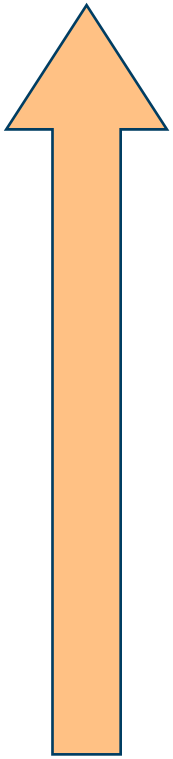


Stateful Web Service ?

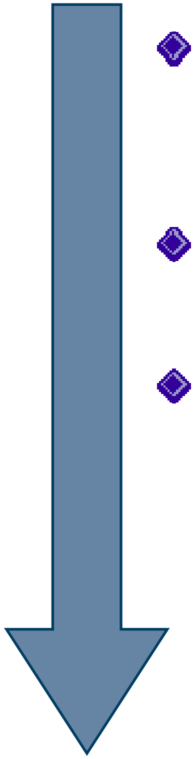


Stateful Web Service

Pros and Cons of the Web Service Model



- increase development efficiency
- increase flexibility
- increase opportunities to generate revenue from services
- increase reusable components/services
- increase interoperability via standards



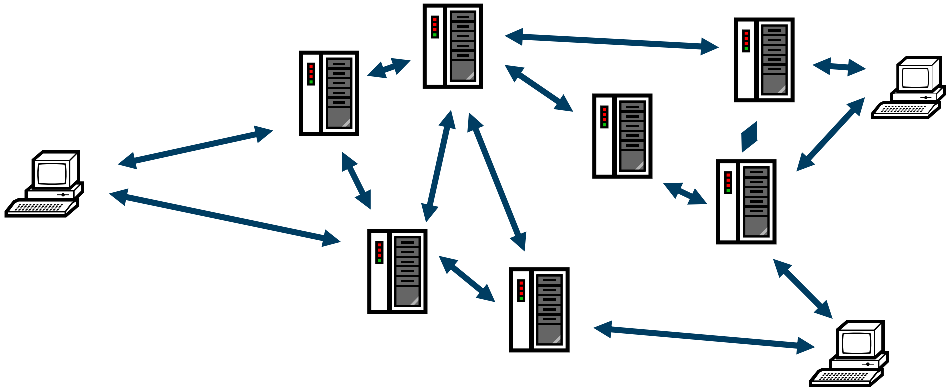
- decreased IT control of software assets
- decreased security / reliability
- decrease trend to in-house centralized systems (more global distribution)

increased flexibility and efficiency for developers

decreased control for IT organizations

Motivation for Model-Driven Development

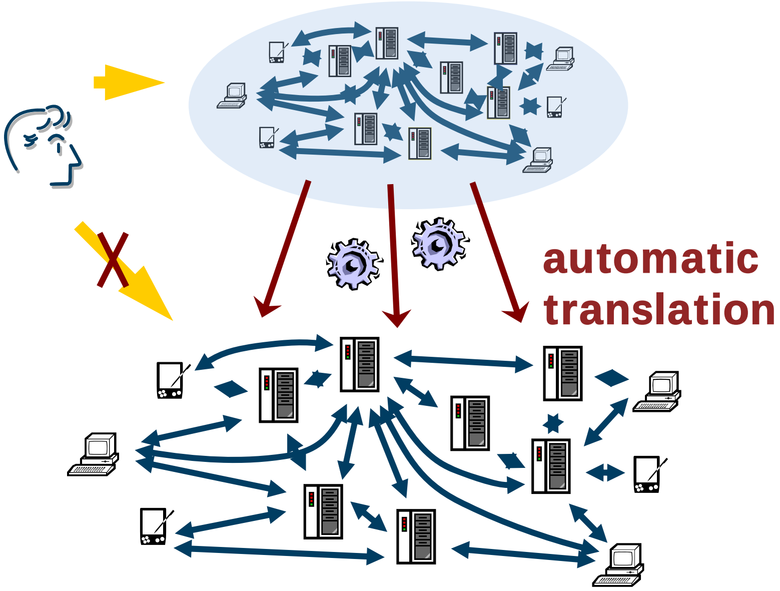
- heterogeneity hinders the development of enterprise distributed systems
- there is (and will never be) complete consensus on
  - hardware
  - operating systems
  - network protocols
  - programming languages
- middleware is intended to solve this problem, but has itself proliferated
  - CORBA, ..
  - COM / .NET, ..
  - Java / J2EE, ..
  - SOAP / WSDL, ...
  - ....



What is Model Driven Development?

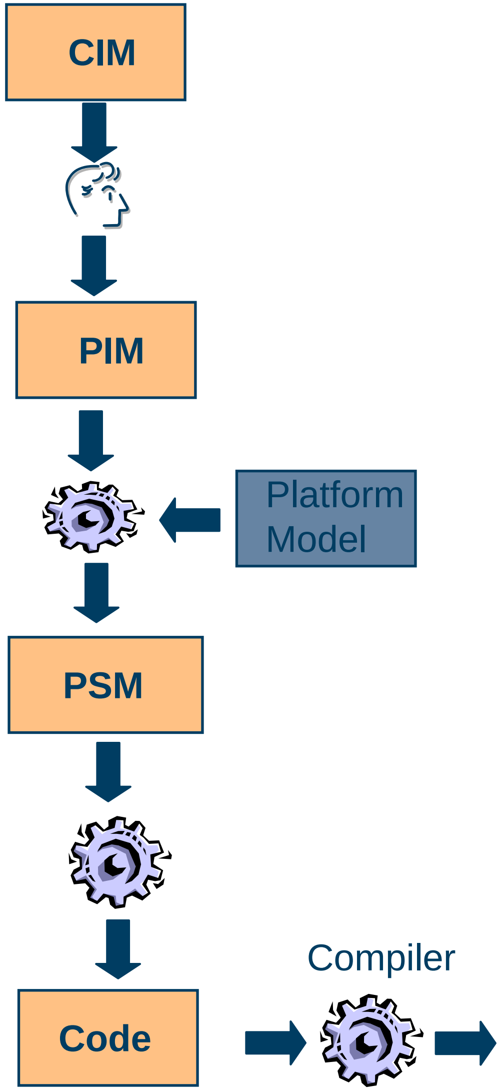
- an approach to IT system specification that separates the specification of system functionality from the implementation of that functionality on a particular technology platform
  - “design once, build on any platform”

- an open, vendor-neutral approach to interoperability using OMG's modeling specifications
  - a software development process driven by the activity of modeling software systems



CIMs, PIMs and PSMs

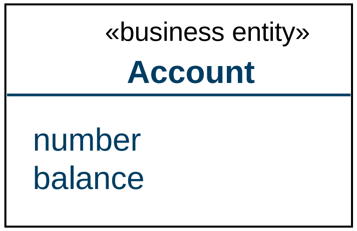
- Computation Independent Models
  - describe the requirements for the system and its environment
  - the details of the structure and processing of the system are hidden or undetermined
- Platform Independent Models
  - focuses on the operation of a system while hiding the details necessary for a particular platform.
  - shows that part of the complete specification that does not change from one platform to another.
- Platform Specific Models
  - combines the platform indep. viewpoint with an additional focus on the detail of the use of a specific platform by a system



PIM and PSM Examples

PIM

- A “formal” specification of the structure and function of a system that abstracts away technical detail
- usually expressed using standard UML

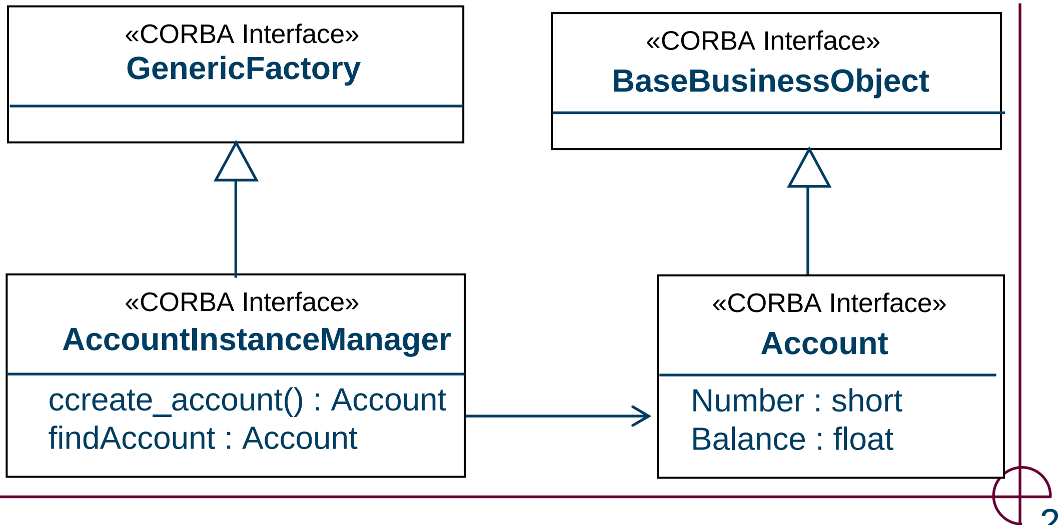


«business entity»
Account

number
balance

PSM

- Specifies how the functionality specified in a PIM is realized on a particular platform
- expressed using UML extended with platform specific UML profiles



«CORBA Interface»
GenericFactory

«CORBA Interface»
BaseBusinessObject

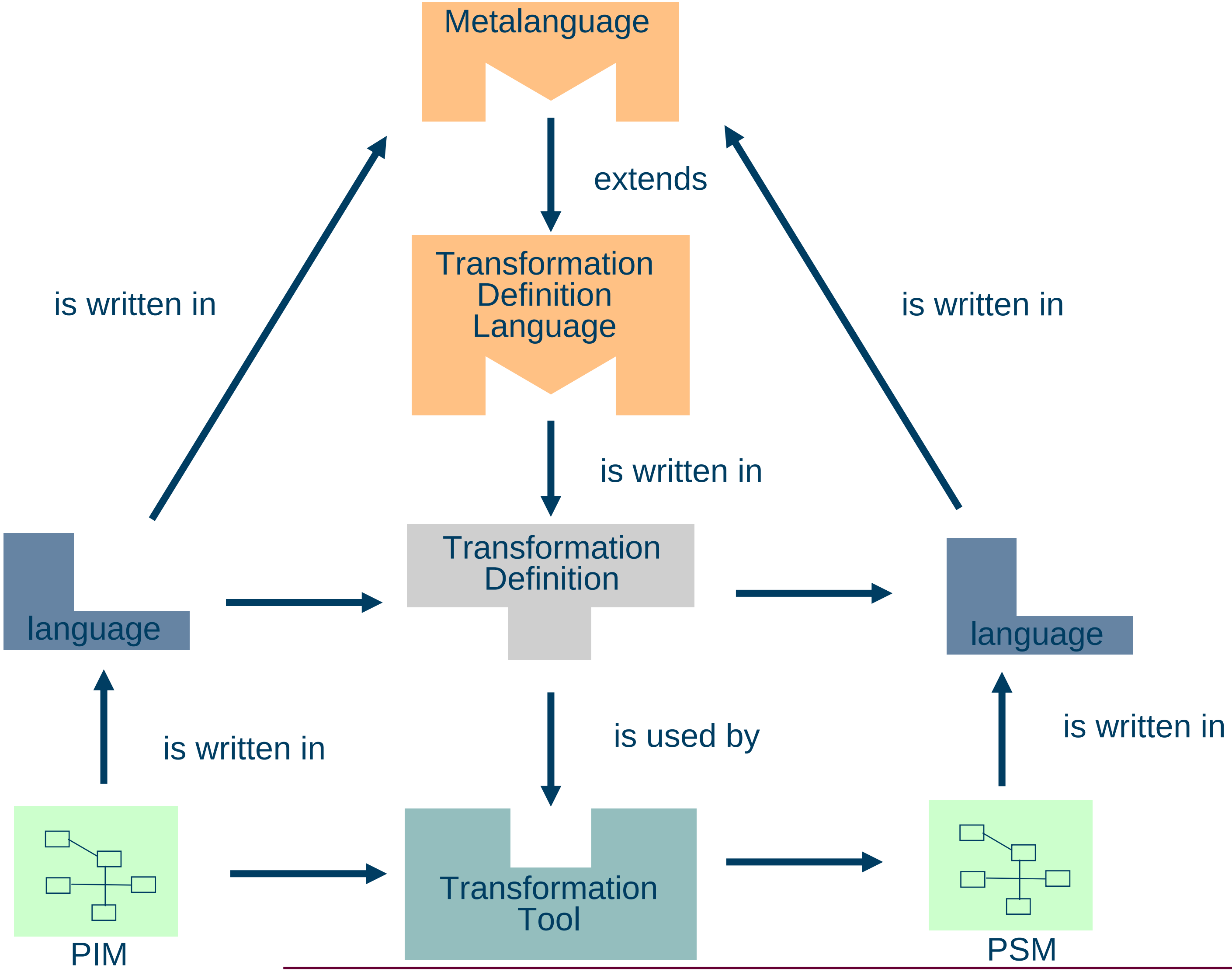
«CORBA Interface»
AccountInstanceManager

ccreate_account() : Account
findAccount : Account

«CORBA Interface»
Account

Number : short
Balance : float

Key Components of MDA



Design by Contract

- a software design principle derived form the legal notion of a contract
  - agreement between two parties in which both accept obligations and on which both can found their rights.
- in SE, provides a means to clearly establish the expectations and responsibilities of an object
  - an object must deliver its services (obligations) if and only if certain stipulations (the rights) are fulfilled
  - provides an exact specification of an object's interface
- an object's contract is formally defined in terms of
  - invariants
  - operation pre and post conditions

Contract Example

- Example
  - For the price of 4 Euros a letter with a maximum weight of 80 grams will be delivered anywhere in the country within 24 hours

Party	**Obligations**	**Rights**
Customer	Pay 4 Euros	Letter delivered within 24 hours
	Supply letter less than 80 grams	
	Specify delivery address within country	
Delivery Company	Deliver letter within 24 hours	Delivery address is within country
		Receive 4 Euros
		Receives letter less than 80 grams

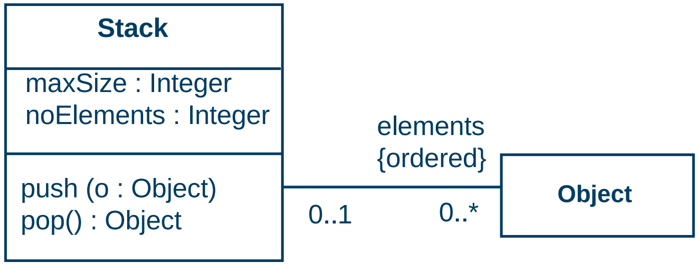
Invariants

- constraints coupled to classes, types and interfaces
  - transcend any one particular operation
- define what must be true for all instances of the class
  - when one of the operations is not executing
- can be viewed as part of the pre and post condition of every operation of a class

```
context Stack
inv: self.noElements <= maxSize
```

```
context Stack
inv: self.noElements >= 0
```

```
context Stack
inv: self.elements->size() = self.noElements
```



Pre and Post Conditions

- post conditions often refer to the value of an attribute or association at the start of an operation's execution
  - achieved by appending @pre to the attribute or association concerned

- the keyword ***result*** can be used to identify the value returned by an operation

```
context Stack::push(o : Object)
pre:    elements-> size() < maxSize
post:   elements->size() = elements@pre->size() + 1
         and elements->last() = o


context Stack::pop():Object
pre:  elements-> size() > 0
post: elements->size() = elements@pre->size() - 1
      and elements = elements@pre->
                              excluding(elements@pre->last())
      and result = elements@pre->last()
```