301AA - Advanced Programming

Lecturer: **Andrea Corradini**
andrea@di.unipi.it
http://pages.di.unipi.it/corradini/

***AP-06**:* *Software Components*

Overview

- Needs of components
- Definition of Component Software
- Components and other programming concepts
- Example of components: short history

➔ Chapters 1 and 4 of *Component Software: Beyond Object-Oriented Programming. C. Szyperski, D. Gruntz, S. Murer, Addison-Wesley, 2002.*

Why **component**-based software?

- Cost of software development
  - from software products to product families
  - need to re-use software to reduce costs
  - better to buy off-the-shelf than re-implementing
  - constructing systems by *composing* components is easier

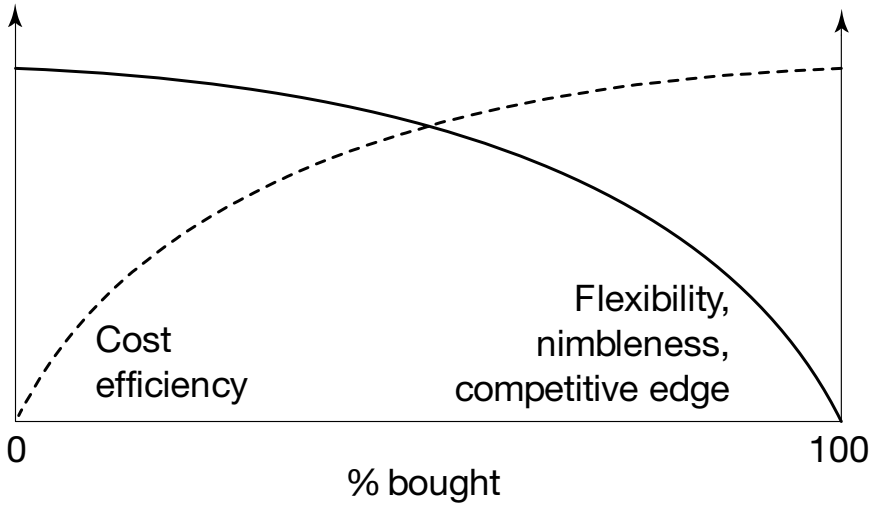


Figure 1.1 Spectrum between make-all and buy-all.

Why **component**-based software?

- ***Component software****: composite systems made of software components*
- More reliable software
  - more reliable to reuse software than to create
  - system requirements can force use of certified components (car industry, aviation, . . .)
- Emergence of a component marketplace
  - Apple's App Store, Android Market, . . .
- Emergence of distributed and concurrent systems
  - we need to build systems composed of independent parts, by necessity

Components as in Engineering…

- Brad Cox's Integrated Circuit analogy:
  - Software components should be like integrated circuits (ICs) (IEEE Software, 1990)
- Other analogies:
  - Components of stereo equipments
  - Lego blocks, …

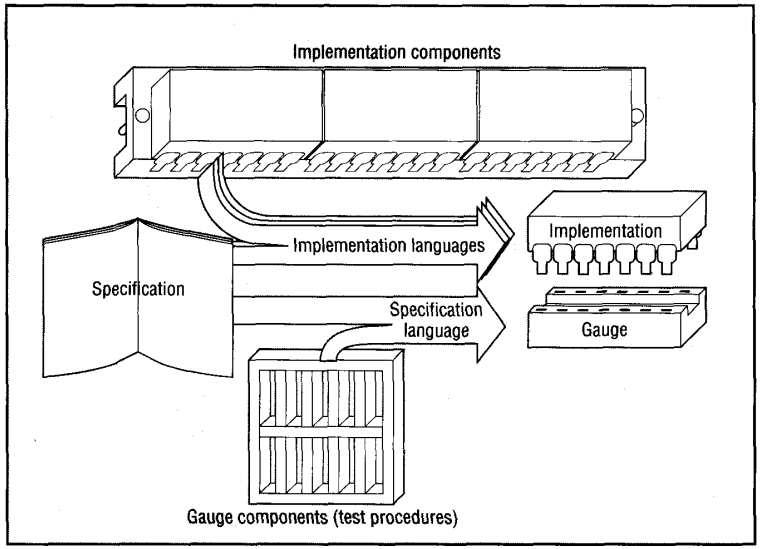


Figure 7. A development process in which specification is given the same emphasis as implementation.

Desiderata for software components

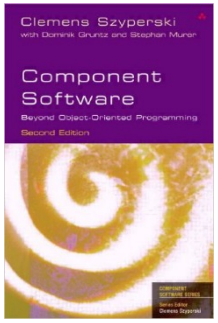
Bertrand Meyer, in *Object Oriented Software Construction (1997)*:

1. **modular** (IC chips, disk drivers, are self-contained: packaged code)
    1. **compatible** (chips or boards that plug in easily, simple interfaces)
    2. **reusable** (same processor IC can serve various purposes)
    3. **extendible** (IC technology can be improved: inheritance)
2. **reliable** (an IC works most of the time!)
    1. **correct** (it does what it's supposed to, according to **specification**)
    2. **robust** (it functions in abnormal conditions)
3. **efficient** (ICs are getting faster and faster!)
4. **portable** (ease of transferring to different platforms)
5. **timely** (released when or before users want it)

Software Components: a definition

"A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third parties." *Clemens Szyperski*

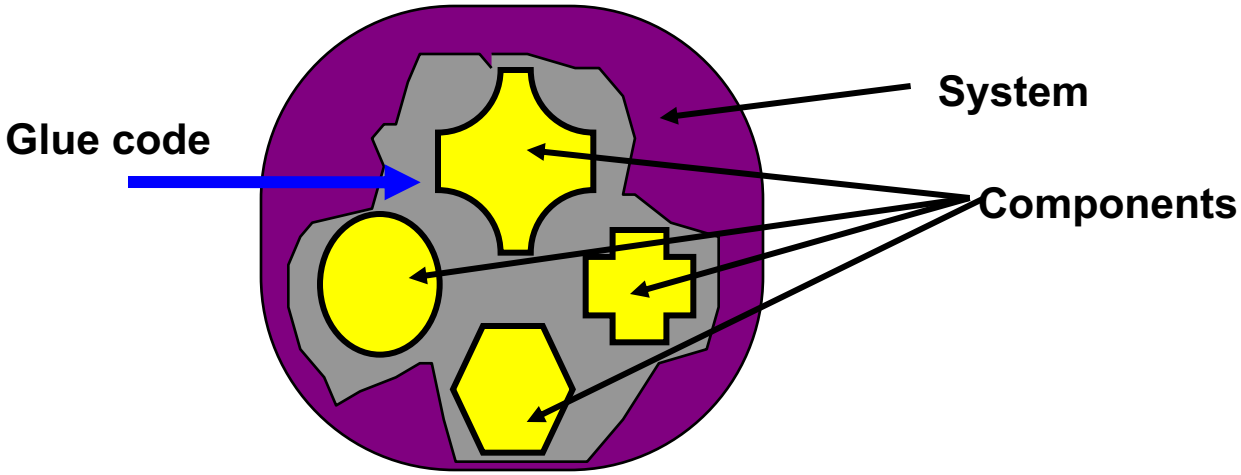
Workshop on Component-Oriented Programming, 1996 European Conference on Object-Oriented Programming



Component Software: Beyond Object-Oriented Programming. C. Szyperski, D. Gruntz, S. Murer, Addison-Wesley, 2002.

Composition unit

A software component is a **unit of composition** with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third party.



- Binary units – black boxes, not source code
- Partial deployment not possible
- System can be built by combining components
- No (externally) observable state
- Indistinguishable from copies

What is a contract?

A software component is a unit of composition with **contractually specified interfaces** and explicit context dependencies only. A software component can be deployed independently and is subject to composition by third party.

- Interface – component specification

- Contract - A specification attached to an interface that mutually binds the clients and providers of the components.
  - Functional Aspects (API)
  - Pre- and post-conditions for the operations specified by API.
  - Non functional aspects (different constrains, environment requirements, etc.)

"Contractually specified interfaces"

- Require mechanism for interface definition, such as Interface Definition Language (IDL)
- Contracts specify more than dependencies and interfaces
  - how the component can be deployed
  - how can be instantiated
  - how the instances behave through the advertised interfaces
- Note: this is more than a set of per-interface specifications
- **Example**: a *queuing component* has a *stable storage* requires interface and *enqueue* and *dequeue* provides interfaces. The contract states that:
  - what is enqueued via one interface can be dequeued via the other
  - instances can only be used by connecting them to a provider implementing the stable storage interface

What is an explicit context dependency?

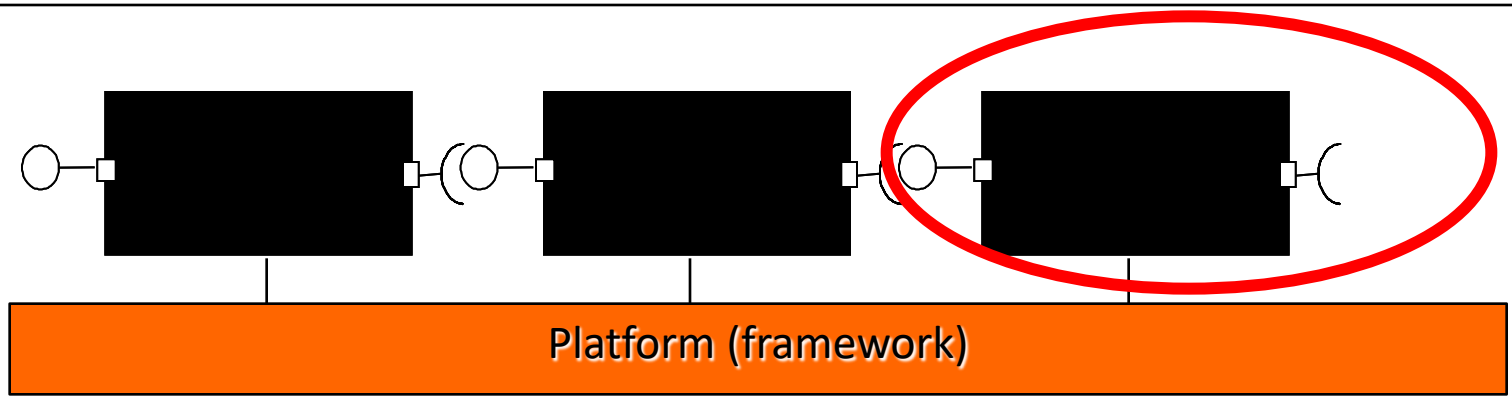
A software component is a unit of composition with contractually specified interfaces and **explicit context dependencies** only. A software component can be deployed independently and is subject to composition by third party.

- Provided and Required Interface

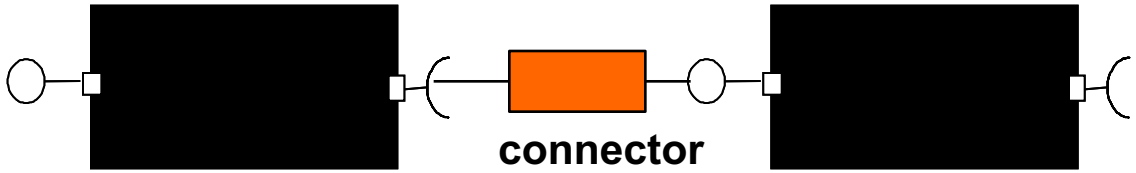
- Context dependencies - Specification of the deployment environment and run-time environment
  - Example: Which tools, platforms, resources or other components are required?

What does it mean deployed independently?

A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be **deployed independently** and is subject to composition by third party.



- Late binding - dependencies are resolved at load or run-time.



What does it mean deployed independently?

A software component is a unit of composition with contractually specified interfaces and explicit context dependencies only. A software component can be deployed independently and is subject to **composition by third party**.

- The component can be plugged into a system or composed with other components by third parties, not aware of the internals of the component.

Basic concepts of a Component Model

- **Component interface**: describes the operations (method calls, messages, . . .) that a component implements and that other components may use
- **Composition mechanism**: the manner in which different components can be composed to work together to accomplish some task.
  For example, using message passing.
- **Component platform**: A platform for the development and execution of components
- Concepts are **language/paradigm agnostic**
- Lays the ground for **language interoperability**

Before Components: Modules

- Support for **modules** in several languages since the 1970's
- Modules as main feature of programming languages for supporting developement of large applications
  - Support *information hiding* through *encapsulation*: explicit import and export lists
  - Reduce risks of *name conflicts;* support *integrity of data abstraction*
- Teams of programmers can work on separate modules in a project
  - No language support for modules in C and Pascal
  - Modula-2 ***modules***, Ada ***packages***
  - Java ***packages*** (?), new notion of module in Java 9

Scoping Rules for Modules

- Scoping: modules encapsulate variables, data types, and subroutines in a package
  - Objects inside are visible to each other
  - Objects inside are not visible outside unless ***exported***
  - Objects outside are visible [*open scopes*], or are not visible inside unless *imported* [*closed scopes*], or are visible with "qualified name" [*selectively open scopes*] (eg: **B.x**)
- A module interface specifies exported variables, data types and subroutines
- The module implementation is compiled separately and implementation details are hidden from the user of the module

Module Types, towards Classes

- Modules as abstraction mechanism: collection of data with operations defined on them (sort of *abstract data type)*
- Various mechanism to get module *instances*:
  - Modules as manager: instance as additional arguments to subroutines (**Modula-2**)
  - Modules as types (**Simula**, **ML**)
- Object-Oriented: Modules (classes) + inheritance
- Many OO languages support a notion of Module (packages) independent from classes

Components and Programming Concepts

- Component can be anything and can contain anything
  - (Collections of) classes, objects, functions/algorithms, data structures
- Typically granularity is coarser than classes
- Components support:
  - Unification of data and function
  - Encapsulation: no visible state
  - Identity: each software entity has a unique identity
  - Use of interfaces to represent specification dependencies

OOP vs COP

- Object orientation is not primarily concerned with **reuse**, but with appropriate domain/problem representation using concepts like:
  - Objects, classes, inheritance, polymorphism
- Experience has shown that the use of OO does not necessarily produce reusable software

CBSE – Component-Based Software Engineering

- Provides methods and tools for
  - Building systems from components
  - Building components as reusable units
  - Performing maintenance by replacement of components and introducing new components into the system
  - System architecture detailed in terms of components

Component Forms

1. Component specification
2. Component interface
3. Component implementation
4. Installed component
5. Component object

Component Specification

- The specification of a unit of software that describes the behavior of a set of *Component Objects* and defines a unit of implementation.
- Behavior is defined as a set of *Interfaces*. A Component Specification is realized as a *Component Implementation*.

Component Interface

- A definition of a set of behaviors that can be offered by a *Component Object* .

Component Implementation

- A realization of *Component Specification*, which is independently deployable.
- This means it can be installed and replaced independently of other components.
  - It does not mean that it is independent of other components – it may have many dependencies.
  - It does not necessarily mean that it is a single physical item, such as a single file.

Installed Component

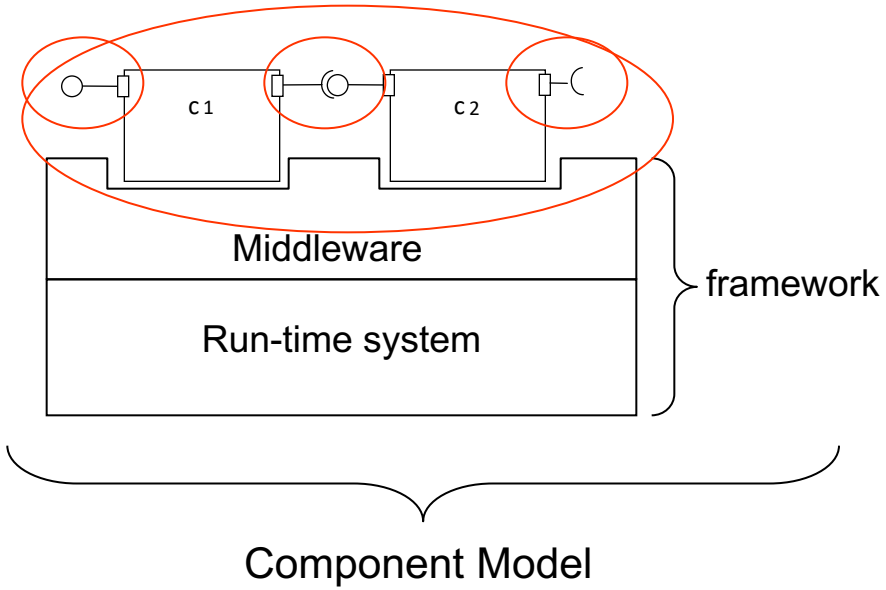
- An installed (or deployed) copy of a *Component Implementation*.
- A Component Implementation is deployed by registering it with the runtime environment.
  - This enables the runtime environment to identify the *Installed Component* to use when creating an instance of the component, or when running one of its operations.

Component Object

- An instance of an *Installed Component*.
- A runtime concept.
- An object with its own data and a unique identity.
- The thing that performs the implemented behavior. An Installed Component may have multiple Component Objects (which require explicit identification) or a single one (which may be implicit).

Summary CBSE – basic definitions

- The basis is the Component
- Components can be assembled according to the rules specified by the component model
- Components are assembled through their interfaces
- A Component Composition is the process of assembling components to form an assembly, a larger component or an application
- Component are performing in the context of a component framework
- All parts conform to the component model
- A component technology is a concrete implementation of a component model



Some successful components: In the past...

- Mathematical libraries
  - NAGLIB - Fortran Library
  - Mathematical and physical functions
- Characteristics
  - ✚ Well defined theory behind the functions - very well standardized
  - ✚ Simple Interface - procedural type of communication between client (application) and server (component)
  - ✚ Well defined input and output
  - ✚ Relative good error handling
  - ✖ Difficult for adaptation (not flexible)

Some successful components: The big ones…

Client - server type

- Database Servers
  - Relational databases, (Object-oriented databases, hierarchical databases)
  - Standard API - SQL
  - ✖ Different dialects of the standard
- X-windows
  - Standard API, callback type of communication
  - ✚ High level of adaptation
  - ✖ Too general - difficult to use it

Even bigger components: Operating systems

- Example - Unix
  - – A general purpose OS, used as a platform for dedicated purposes
  - – Standard API - POSIX
  - ✚ Commands used as components in a shell-process
  - ✚ Low-level but well-defined interfaces (file sharing, pipes and filter)
  - ✖ Different variants, POSIX is not sufficient
  - ✖ Not a real component behavior (difficult to replace or update)
- MS Windows ...

More recent components…

- **Plugin architectures** (finer-grained components)
  - Netscape's Navigator web browsers
  - Active Server Pages (ASP) and Java Server Pages (JSP) architectures for web servers
- Microsoft's **Visual Basic**
- Java **Beans**, Enterprise JavaBeans (EJB)
- Microsoft's **COM+**
- Android's component based apps
- Modern application and integration servers around J2EE and COM+ / .NET

What do all the above examples have in common?

- In all cases there is an **infrastructure** providing rich foundational functionality for the addressed domain.
- Components can be purchased from **independent providers** and deployed by clients.
- The components provide services that are substantial enough to make **duplication of their development** too difficult or **not cost- effective**.
- Multiple components from different sources **can coexist** in the same installation.

- Components exist on a **level of abstraction** where they directly mean something to the deploying client
- With Visual Basic, this is obvious – a **control** has a direct visual representation, displayable and editable properties, and has meaning that is closely attached to its appearance.
- With **plugins**, the client gains some explicable, high-level feature and the plugin itself is a user-installed and configured component

Modules vs. Components

- Several component-related concepts already present in modules
- Modules as part of a program, component as part of a system
- Components can include static resources
- Modules may expose observable state
- Modules encompassed by classes in OO languages in the 1990's
- Now present in most modern languages