301AA - Advanced Programming

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***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

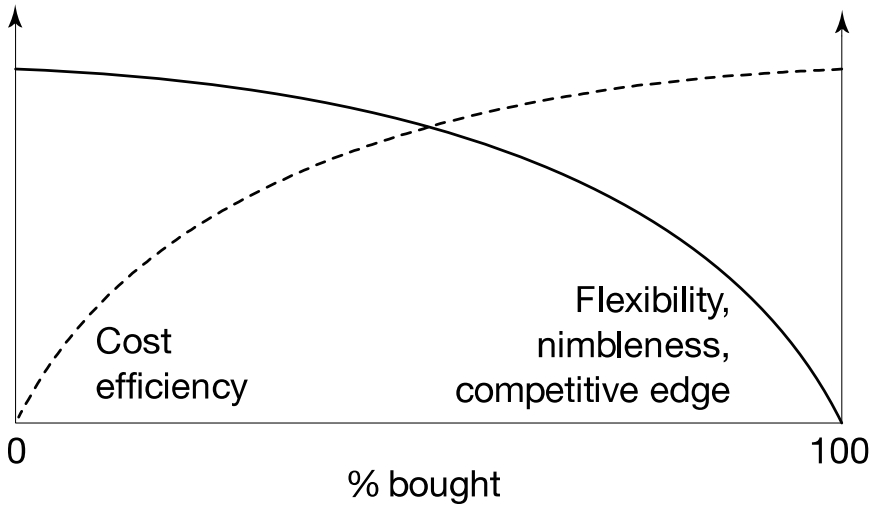


Figure 1.1 Spectrum between make-all and buy-all.

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, …

wise intangible software products like Stack or Set. Making software tangible and observable, rather than intangible and speculative, is the first step to making software engineering and computer science a reality.

Test procedures collect operational, or indirect, measurements of what we'd really like to know, the product's quality as perceived by the customer. They monitor the consumer's interface, rather than our traditional focus on the producer's interface (by counting lines of code, cyclomatic complexity, Halstead metrics, and the like). This knowledge of how product quality varies over time can then be fed back to improve the process through statistical quality-control techniques, as described by W. Edwards Deming[6], that play such a key role today in manufacturing.

Implications. The novelty of this approach is threefold:

this implies: a shift in power away from those who produce the code to those who consume it — from those who control the implementations to those who control the specifications. Three implications are:

- Specification/testing languages could lead to less reliance on source code, new ways of documenting code for reuse, and fundamentally new ideas for classifying large libraries of code so it can be located readily in reference manuals, component catalogs, and browsers.
- Specification/testing languages could free us from our preoccupation with standardized processes (programming languages) and our neglect of standardized products (software components). Producers would be freed to use whatever language is best for each task, knowing that the consumer will compile the specification to determine whether the result is as specified.
- Specification/testing languages can

Desiderata for software components

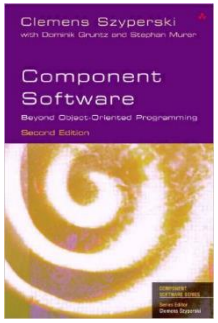
Bertrand Meyer, in *Object Oriented Software Construction (1997)*:

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*

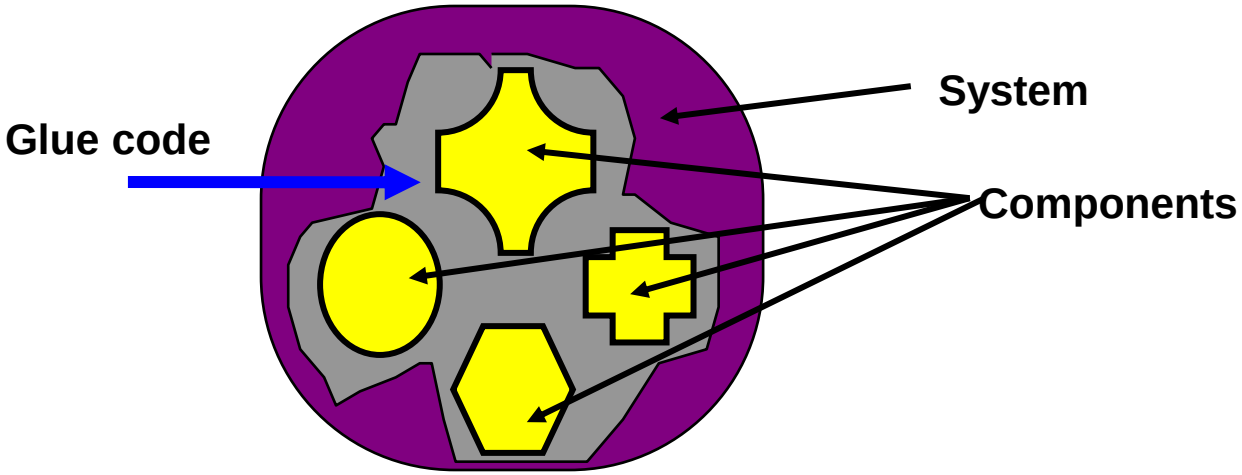
Workshop on Component-Oriented Programming, 1996 European Conference on Object-Oriented Programming



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”?

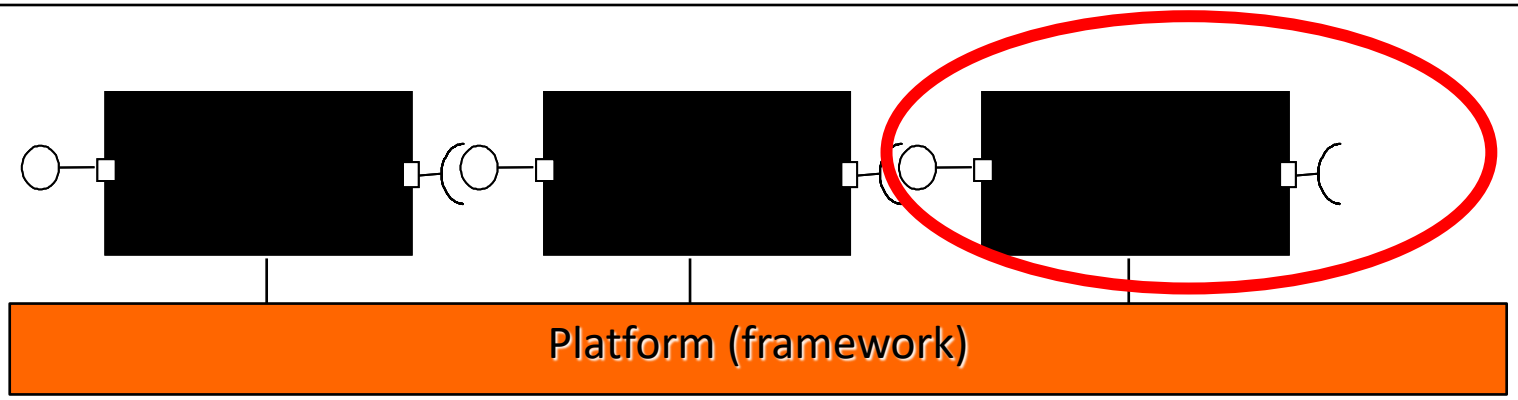
A software component is a unit of composition with contractually specified interfaces and **explicit context dependencies** only. A software component can be deployed independently and is subject to composition by third party.

- Provided and Required Interface

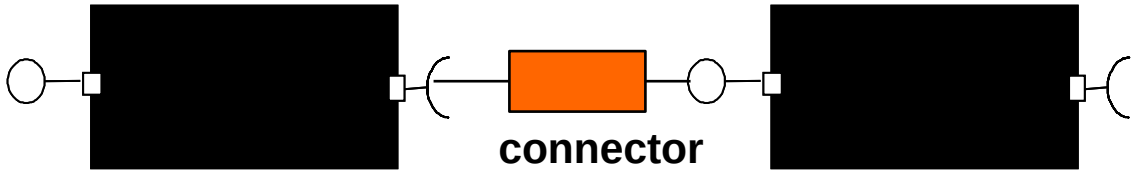
- Context dependencies - Specification of the deployment environment and run-time environment
  - Example: Which tools, platforms, resources or other components are required?

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 "composition by third party"?

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

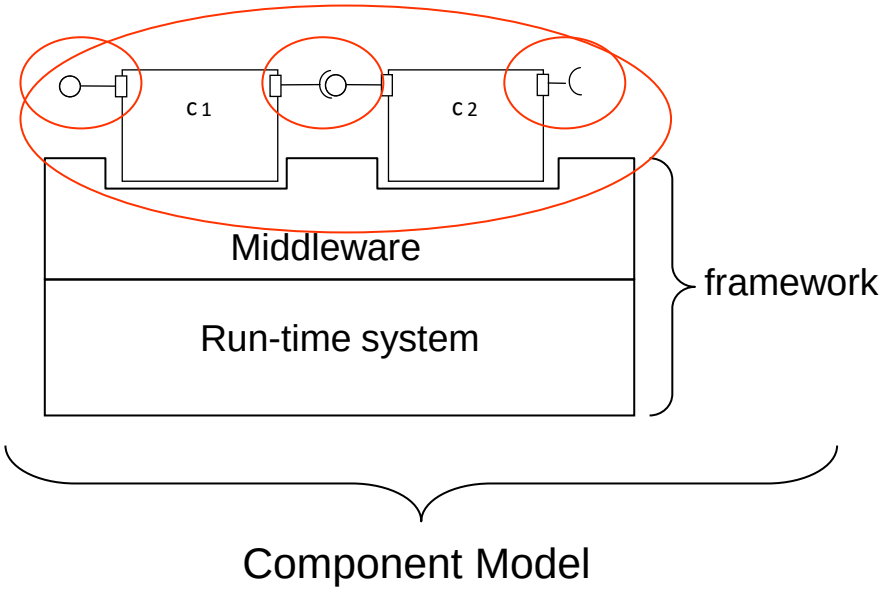
- An installed (or deployed) copy of a *Component Implementation*.
- A Component Implementation is deployed by registering it with the runtime environment.
  - This enables the runtime environment to identify the *Installed Component* to use when creating an instance of the component, or when running 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
  - 6 Different dialects of the standard
- X-windows
  - Standard API, callback type of communication
  - : High level of adaptation
  - 6 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)
  - 6 Different variants, POSIX is not sufficient
  - 6 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