Chapter 15 – Software Reuse

Topics covered

- ✧ The reuse landscape
- ✧ Application frameworks
- ✧ Software product lines

Software reuse

- In most engineering disciplines, systems are designed by composing existing components that have been used in other systems.
- Software engineering has been more focused on original development but it is now recognised that to achieve better software, more quickly and at lower cost, we need a design process that is based on systematic software reuse.
- There has been a major switch to reuse-based development over the past 10 years.

Reuse-based software engineering

- System reuse
  - Complete systems, which may include several application programs may be reused.
- Application reuse
  - An application may be reused either by incorporating it without change into other or by developing application families.
- Component reuse
  - Components of an application from sub-systems to single objects may be reused.
- Object and function reuse
  - Small-scale software components that implement a single well-defined object or function may be reused.

Benefits of software reuse

Benefit	Explanation
Accelerated development	Bringing a system to market as early as possible is often more important than overall development costs. Reusing software can speed up system production because both development and validation time may be reduced.
Effective use of specialists	Instead of doing the same work over and over again, application specialists can develop reusable software that encapsulates their knowledge.
Increased dependability	Reused software, which has been tried and tested in working systems, should be more dependable than new software. Its design and implementation faults should have been found and fixed.

Benefits of software reuse

Benefit	Explanation
Lower development costs	Development costs are proportional to the size of the software being developed. Reusing software means that fewer lines of code have to be written.
Reduced process risk	The cost of existing software is already known, whereas the costs of development are always a matter of judgment. This is an important factor for project management because it reduces the margin of error in project cost estimation. This is particularly true when relatively large software components such as subsystems are reused.
Standards compliance	Some standards, such as user interface standards, can be implemented as a set of reusable components. For example, if menus in a user interface are implemented using reusable components, all applications present the same menu formats to users. The use of standard user interfaces improves dependability because users make fewer mistakes when presented with a familiar interface.

Problems with reuse

Problem	Explanation
Creating, maintaining, and using a component library	Populating a reusable component library and ensuring the software developers can use this library can be expensive. Development processes have to be adapted to ensure that the library is used.
Finding, understanding, and adapting reusable components	Software components have to be discovered in a library, understood and, sometimes, adapted to work in a new environment. Engineers must be reasonably confident of finding a component in the library before they include a component search as part of their normal development process.
Increased maintenance costs	If the source code of a reused software system or component is not available then maintenance costs may be higher because the reused elements of the system may become increasingly incompatible with system changes.

Problems with reuse

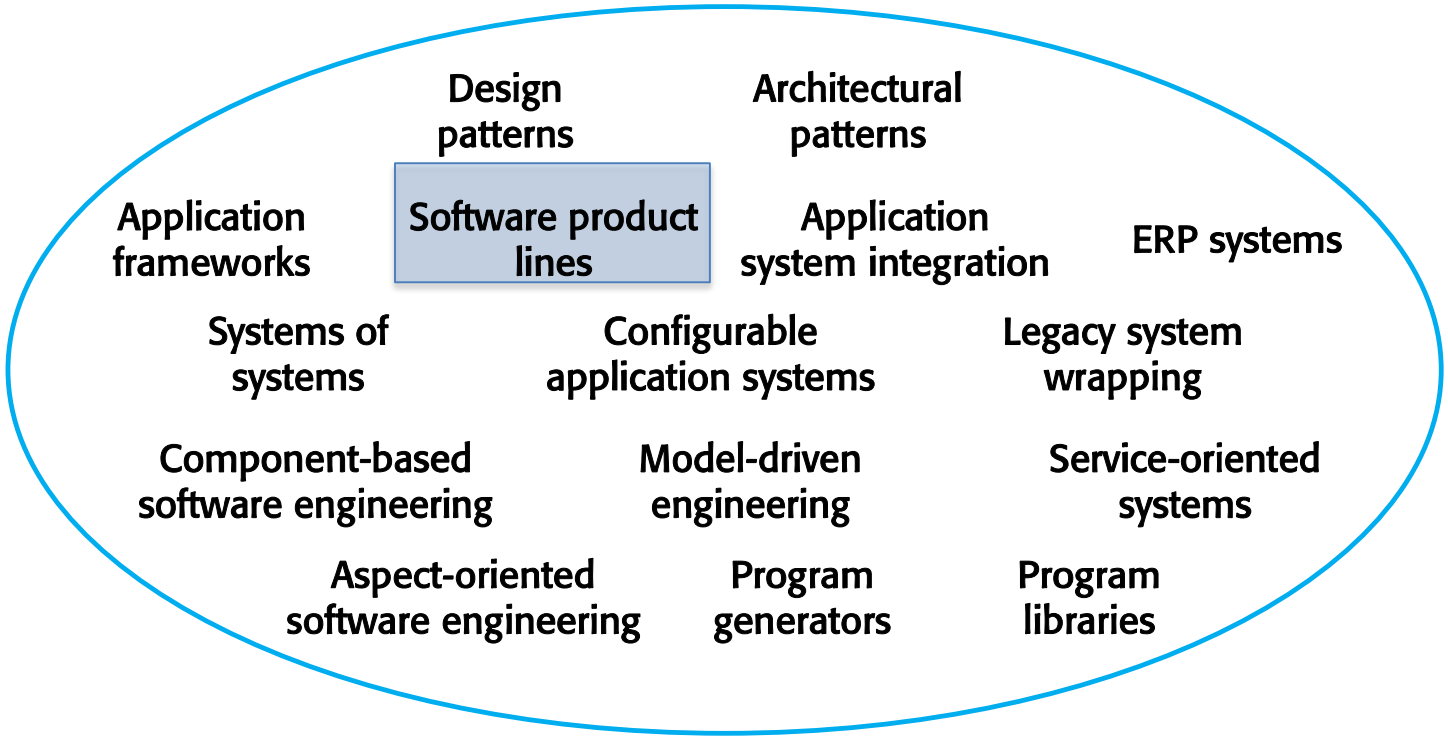
Problem	Explanation
Lack of tool support	Some software tools do not support development with reuse. It may be difficult or impossible to integrate these tools with a component library system. The software process assumed by these tools may not take reuse into account. This is particularly true for tools that support embedded systems engineering, less so for object-oriented development tools.
Not-invented-here syndrome	Some software engineers prefer to rewrite components because they believe they can improve on them. This is partly to do with trust and partly to do with the fact that writing original software is seen as more challenging than reusing other people's software.

The reuse landscape

The reuse landscape

- Although reuse is often simply thought of as the reuse of system components, there are many different approaches to reuse that may be used.
- Reuse is possible at a range of levels from simple functions to complete application systems.
- The reuse landscape covers the range of possible reuse techniques.

The reuse landscape



Approaches that support software reuse

Approach	Description
Application frameworks	Collections of abstract and concrete classes are adapted and extended to create application systems.
Application system integration	Two or more application systems are integrated to provide extended functionality
Architectural patterns	Standard software architectures that support common types of application system are used as the basis of applications.
Aspect-oriented software development	Shared components are woven into an application at different places when the program is compiled.
Component-based software engineering	Systems are developed by integrating components (collections of objects) that conform to component-model standards. Described in Chapter 16.

Approaches that support software reuse

Approach	Description
Configurable application systems	Domain-specific systems are designed so that they can be configured to the needs of specific system customers.
Design patterns	Generic abstractions that occur across applications are represented as design patterns showing abstract and concrete objects and interactions. Described in Chapter 7.
ERP systems	Large-scale systems that encapsulate generic business functionality and rules are configured for an organization. ERP is a category of business-management software—typically a suite of integrated applications—that an organization can use to collect, store, manage and interpret data from many business activities,
Legacy system wrapping	Legacy systems are 'wrapped' by defining a set of interfaces and providing access to these legacy systems through these interfaces.
Model-driven engineering	Software is represented as domain models and implementation independent models and code is generated from these models.

Approaches that support software reuse

Approach	Description
Program generators	A generator system embeds knowledge of a type of application and is used to generate systems in that domain from a user-supplied system model.
Program libraries	Class and function libraries that implement commonly used abstractions are available for reuse.
Service-oriented systems	Systems are developed by linking shared services, which may be externally provided.
Software product lines	An application type is generalized around a common architecture so that it can be adapted for different customers.
Systems of systems	Two or more distributed systems are integrated to create a new system.

Reuse planning factors

- The development schedule for the software.
- The expected software lifetime.
- The background, skills and experience of the development team.
- The criticality of the software and its non-functional requirements.
- The application domain.
- The execution platform for the software.

Software Product Lines

SPL: Definition

- A *software product line* is a set of software-intensive systems that share a common, managed set of features
  - satisfying the specific needs of a particular market segment or mission and
  - are developed from a common set of core assets in a prescribed way.
- *Software product line practice* is the systematic use of core assets to assemble, instantiate, or generate the multiple products that constitute a software product line.
- Software product line practice involves strategic, large-grained reuse.

Core assets

- *Core assets* are those reusable artifacts and resources that form the basis for the software product line.
- Core assets often include, but are not limited to, the architecture, reusable software components, domain models, requirements statements, documentation, specifications, performance models, schedules, budgets, test plans, test cases, work plans, and process descriptions.
- The architecture is key among the collection of core assets.

Benefits

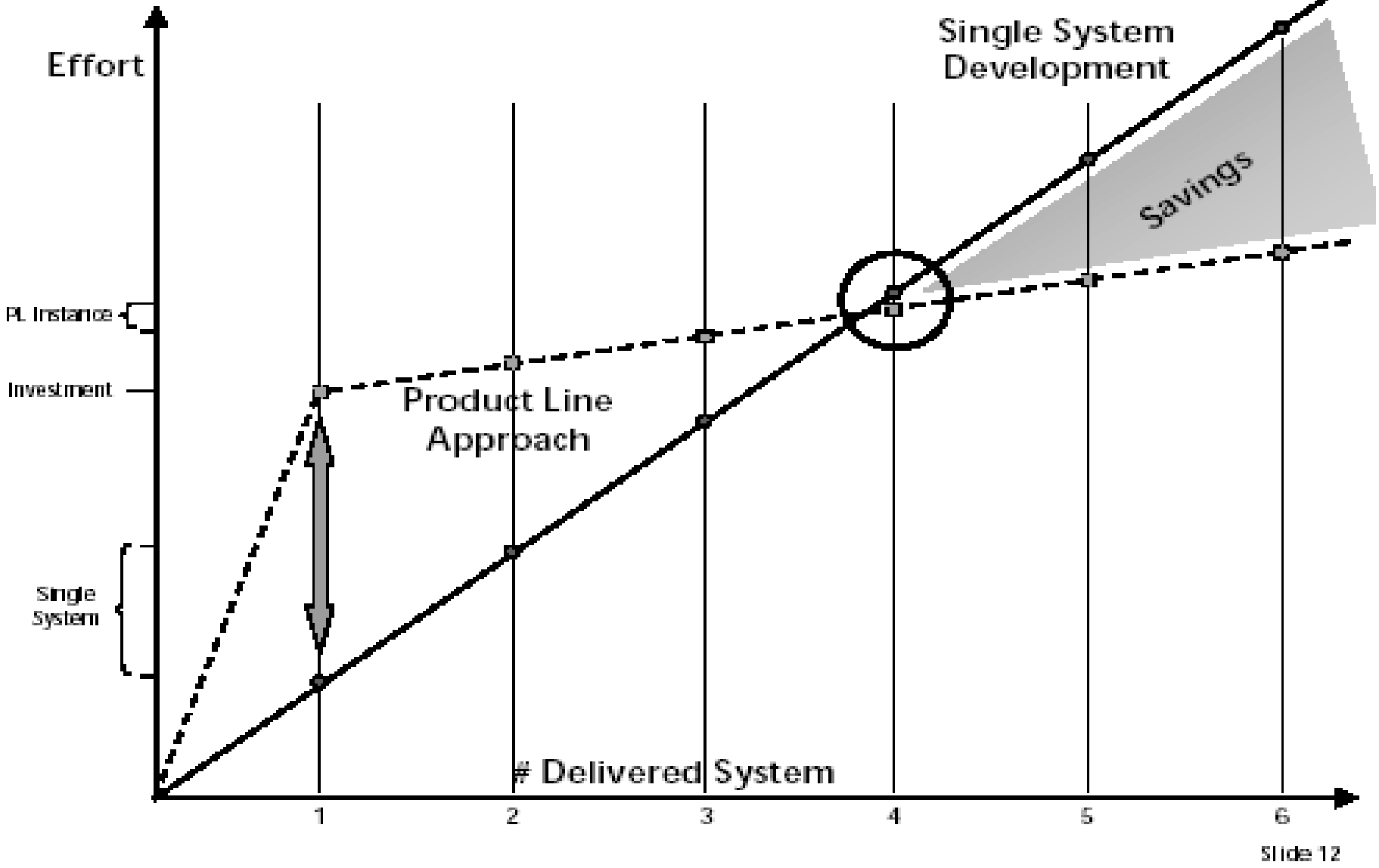
- large-scale productivity gains
- decreased time to market
- increased product quality
- decreased product risk
- increased market agility
- increased customer satisfaction
- more efficient use of human resources
- ability to effect mass customization
- ability to maintain market presence
- ability to sustain unprecedented growth

Domain

- A *domain* is a specialized body of knowledge, an area of expertise, or a collection of related functionality.
- For example, the telecommunications domain is a set of telecommunications functionality, which, in turn, consists of other domains such as switching, protocols, telephony, and networks.
- A telecommunications software product line is a specific set of software systems that provide some of that functionality.

How is production made more economical?

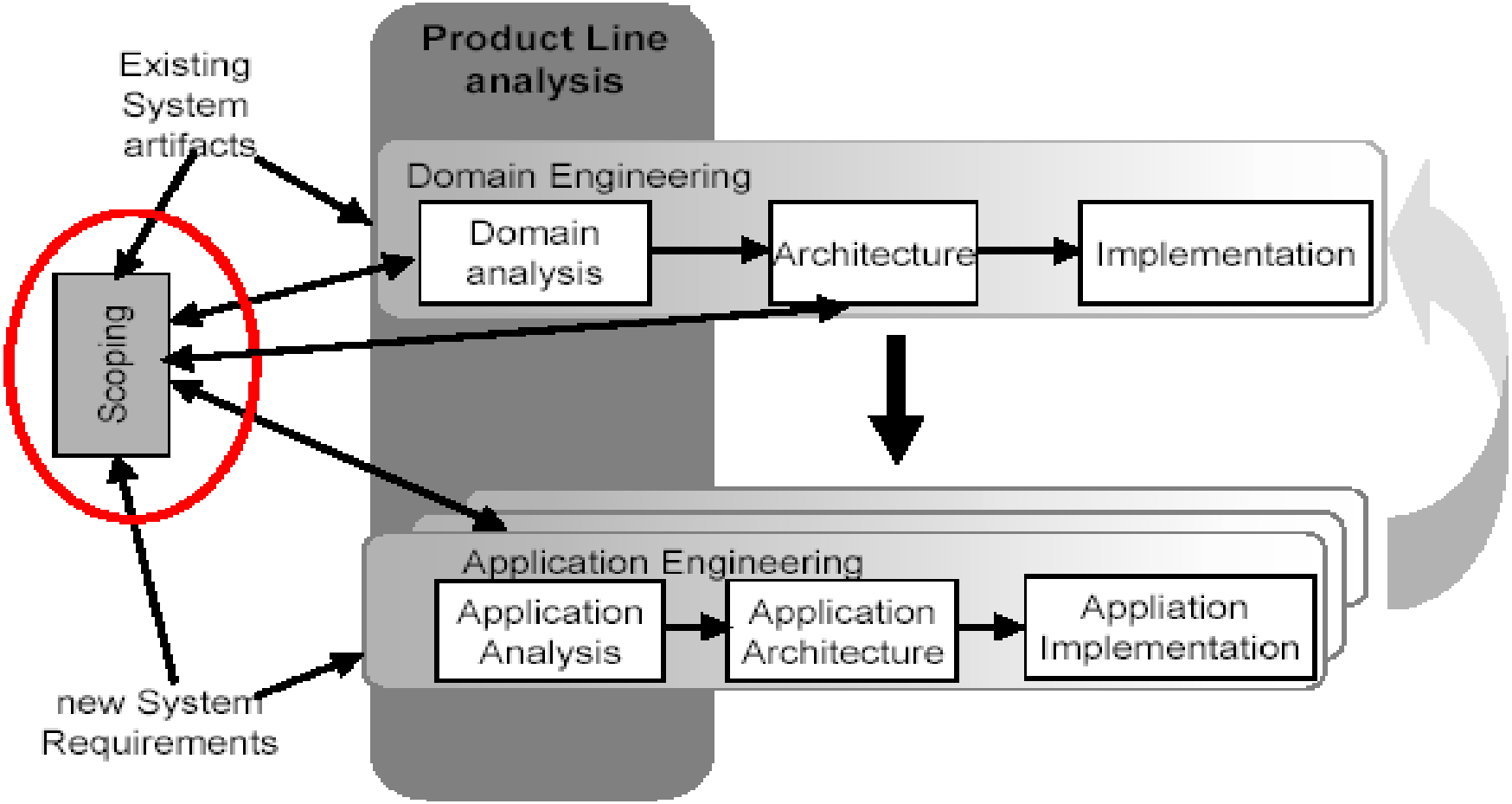
- Each product is formed by
  - taking applicable components from the base of common assets,
  - tailoring them as necessary through preplanned variation mechanisms such as parameterization or inheritance,
  - adding any new components that may be necessary,
  - assembling the collection according to the rules of a common, product-line-wide architecture.
- Building a new product (system) becomes more a matter of assembly or generation than one of creation;
  - the predominant activity is integration rather than programming.
- For each software product line, there is a predefined guide or plan that specifies the exact product-building approach.


Effort
Single System Development
Savings
PL Instance
Investment
Product Line Approach
Single System
Delivered System
1
2
3
4
5
6

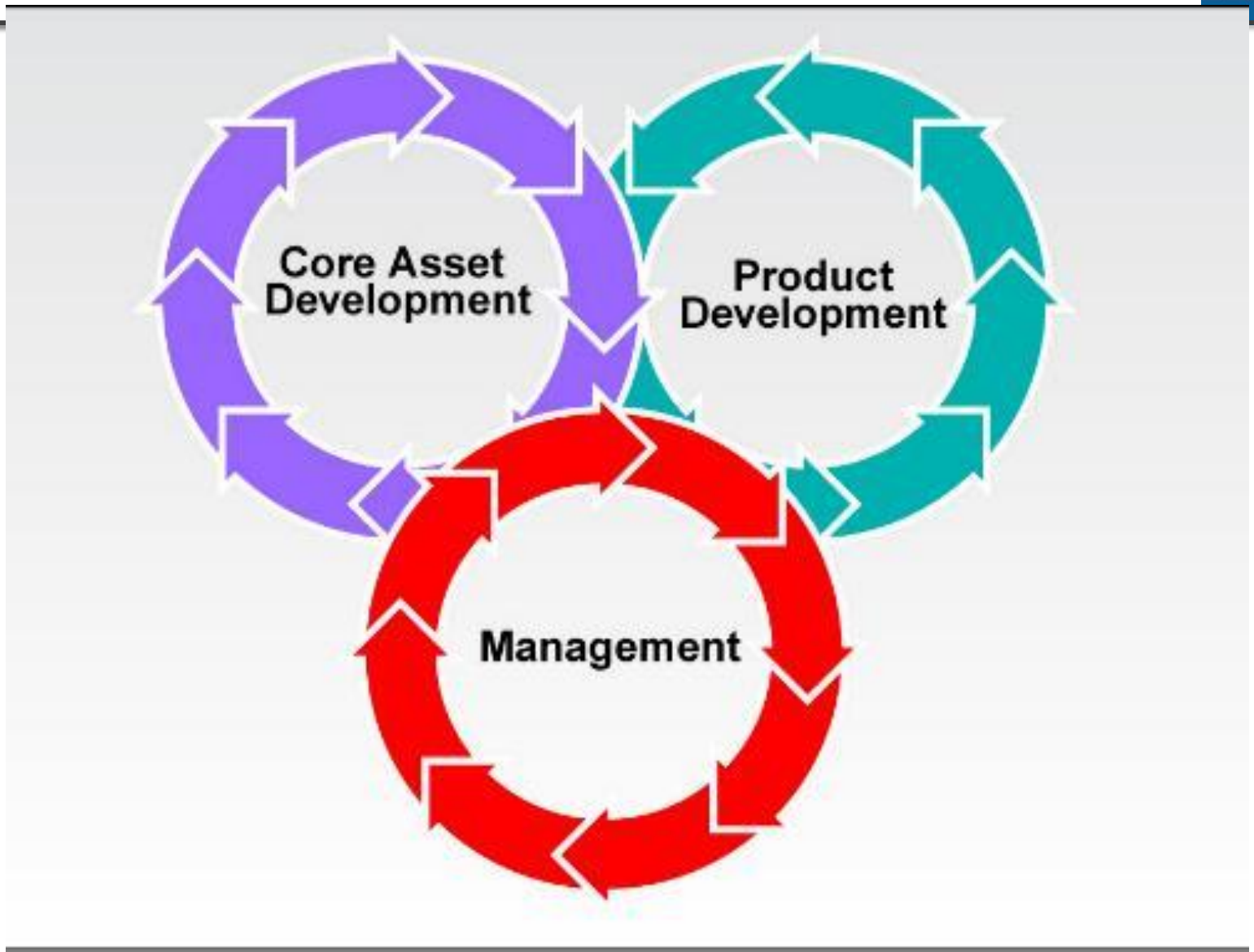
Other concepts

- The *product family* is that set of products we call the product line.
- The software assets in the core asset base are sometimes called a *platform*.
- What we call core asset development is sometimes referred to as *domain engineering*,
- What we call product development is sometimes referred to as *application engineering*.

SPL processes



SPL activities



Requirements engineering for product lines

- **Requirements elicitation** for a product line must capture anticipated variations explicitly over the foreseeable lifetime of the product line.
- This means that the community of stakeholders is probably larger than for single-system requirements elicitation
  - it may well include domain experts, market experts, and others.
- Requirements elicitation focuses on:
  - the scope, explicitly capturing the anticipated variation by the application of domain analysis techniques,
  - the incorporation of existing domain analysis models,
  - and the incorporation of use cases that capture the variations that are expected to occur over the lifetime of the product line

RE for SPL

- **Requirements analysis** for a product line involves finding commonalities and identifying variations.
  - Requirements analysis includes a commonality and variability analysis (a technique used frequently in domain analysis) on the elicited product line requirements to identify the opportunities for large-grained reuse within the product line.
  - Two such techniques are Feature-Oriented Domain Analysis (F!%#) and use cases

Domain analysis techniques

- These techniques can be used:
  - to expand the scope of the requirements elicitation,
  - to identify and plan for anticipated changes,
  - to determine fundamental commonalities and variations in the products of the product line,
  - to support the creation of robust architectures.

- Feature modeling facilitates the identification and analysis of the product line's commonality and variability and provides a natural vehicle for requirements specification.
- Other techniques:
  - Use case modeling

Feature modeling

- This technique can be used to complement object and use case modeling and to organize the results of the commonality and variability analysis in preparation for reuse.
- Features are user-visible aspects or characteristics of a system that are organized into a tree of And/Or nodes to identify the commonalities and variabilities within the system.
- Feature modeling is an integral part of the F!%# method and the feature-oriented reuse method (FORM).
  - The commonalities and variabilities within those features are then exploited to create a set of reference models (that is, software architectures and components) that can be used to implement the products of that family.

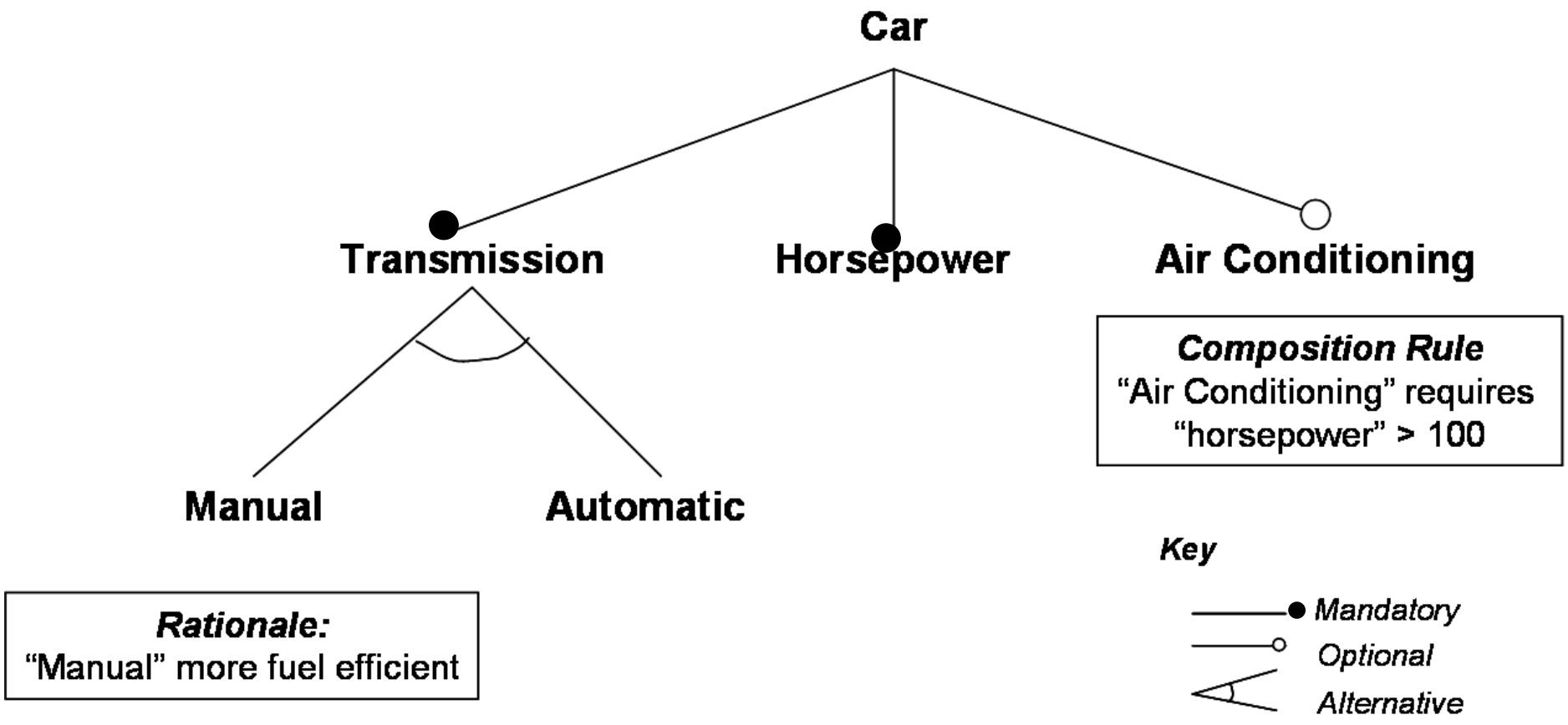
Features and feature model

- A *feature* is a system property that is relevant to some stakeholder and is used to capture commonalities or discriminate among products in a product line.
- A *feature model* consists of one or more *feature diagrams*, which organize features into hierarchies.

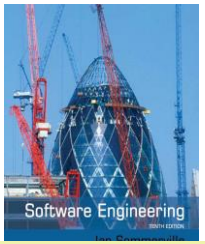
Feature-Oriented Domain Analysis

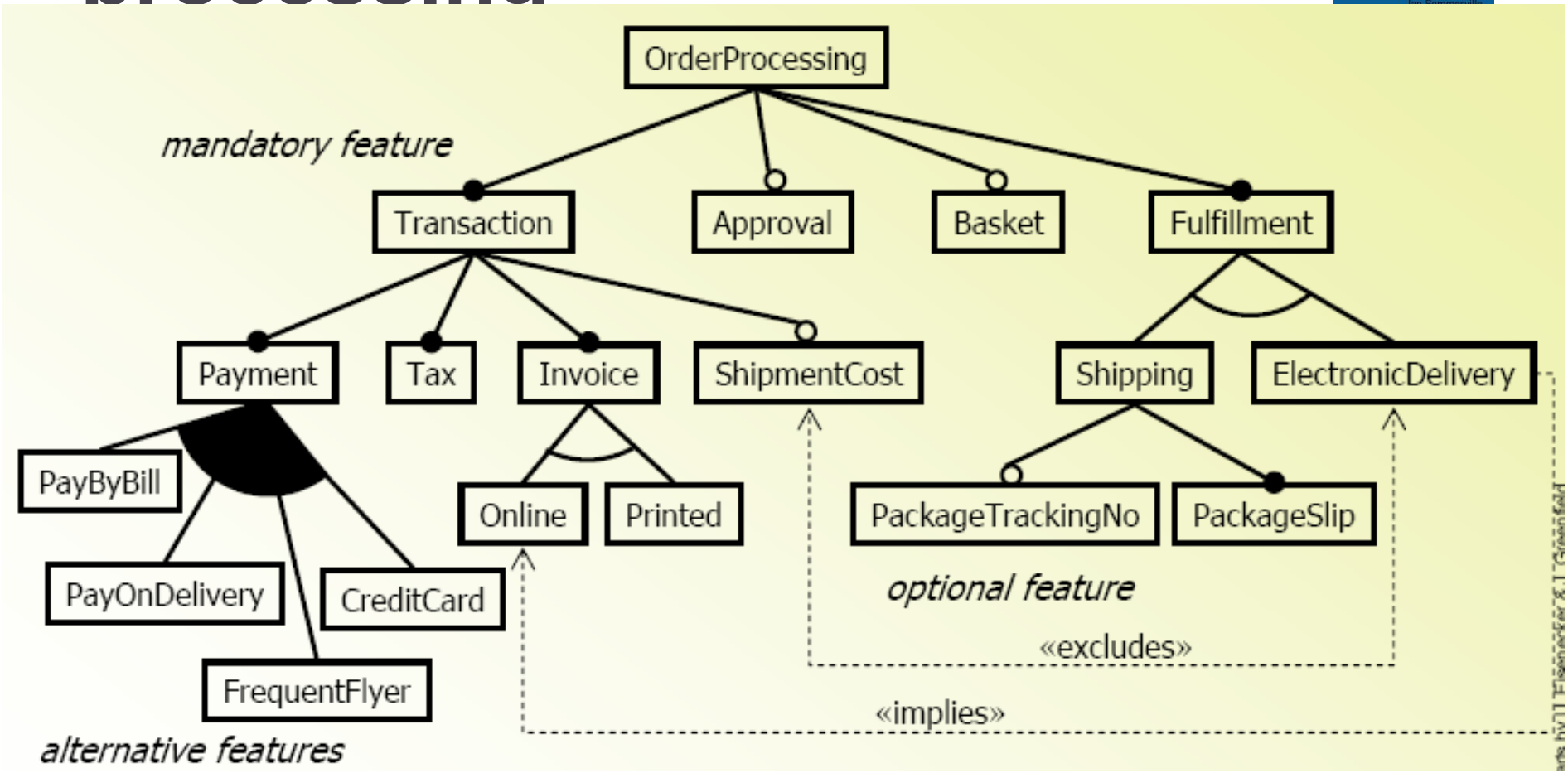
- A F!%# feature model comprises the following elements:
  - **Feature diagram.** The diagram depicts a hierarchical decomposition of features with mandatory (must have), alternative (selection from many) and optional (may or may not have) relationships.
  - **Feature definitions.** Description of all features
  - **Composition rules.** These rules indicate which feature combinations are valid and which are not.
  - **Rationale for features.** The rationale for choosing or not choosing a particular feature, indicating the trade-offs.

Feature diagram of a car



Feature model for order processing





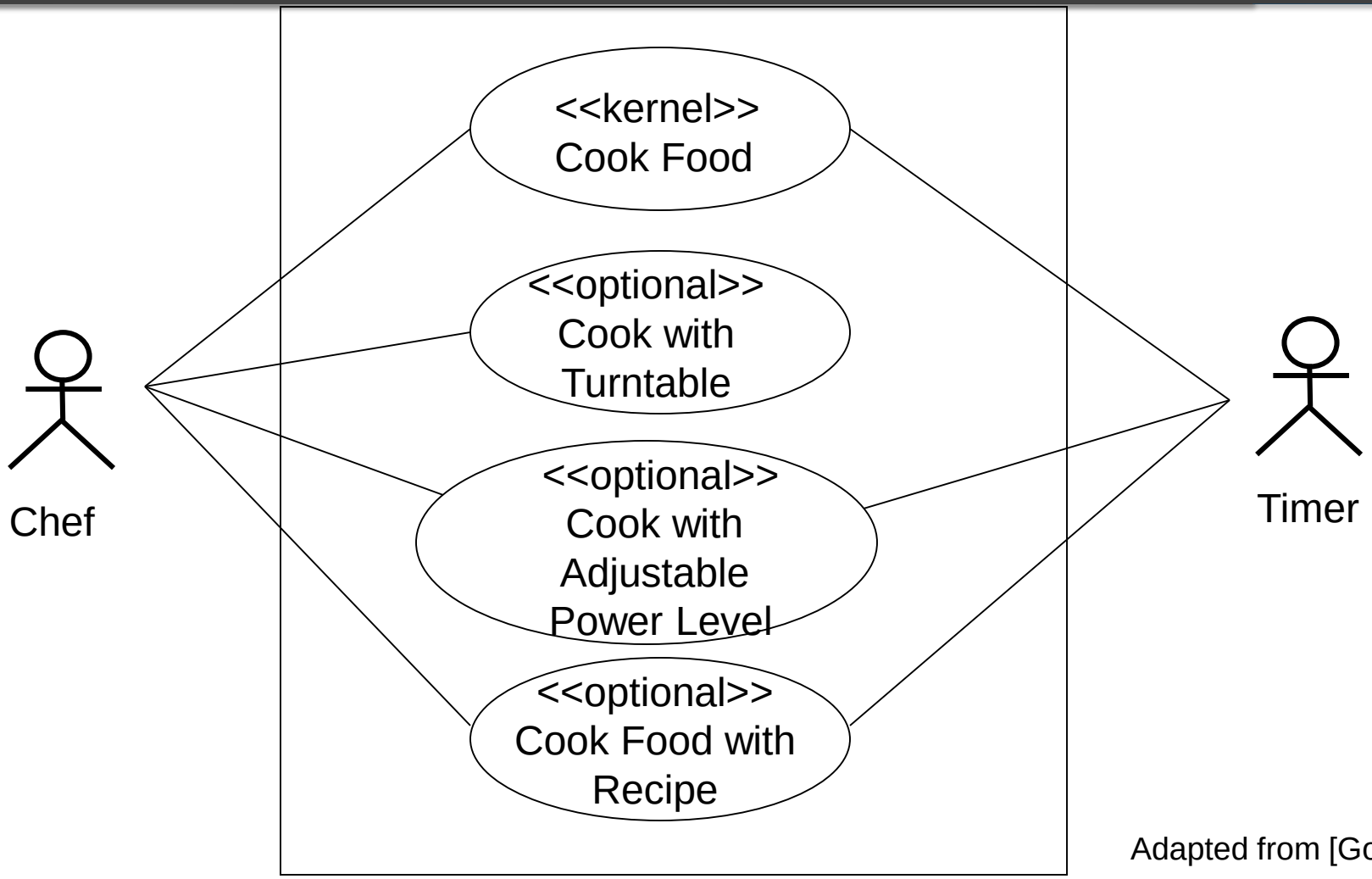
UC Modeling with the PLUS approach [H.Gomaa]

- ✧ Use case modeling
  - <<kernel>>, <<optional>>, <<alternative>>
- ✧ Feature modeling
- ✧ Static modeling
  - <<kernel>>, <<optional>>, <<alternative>> in UML class diagrams

PLUS: UC modeling

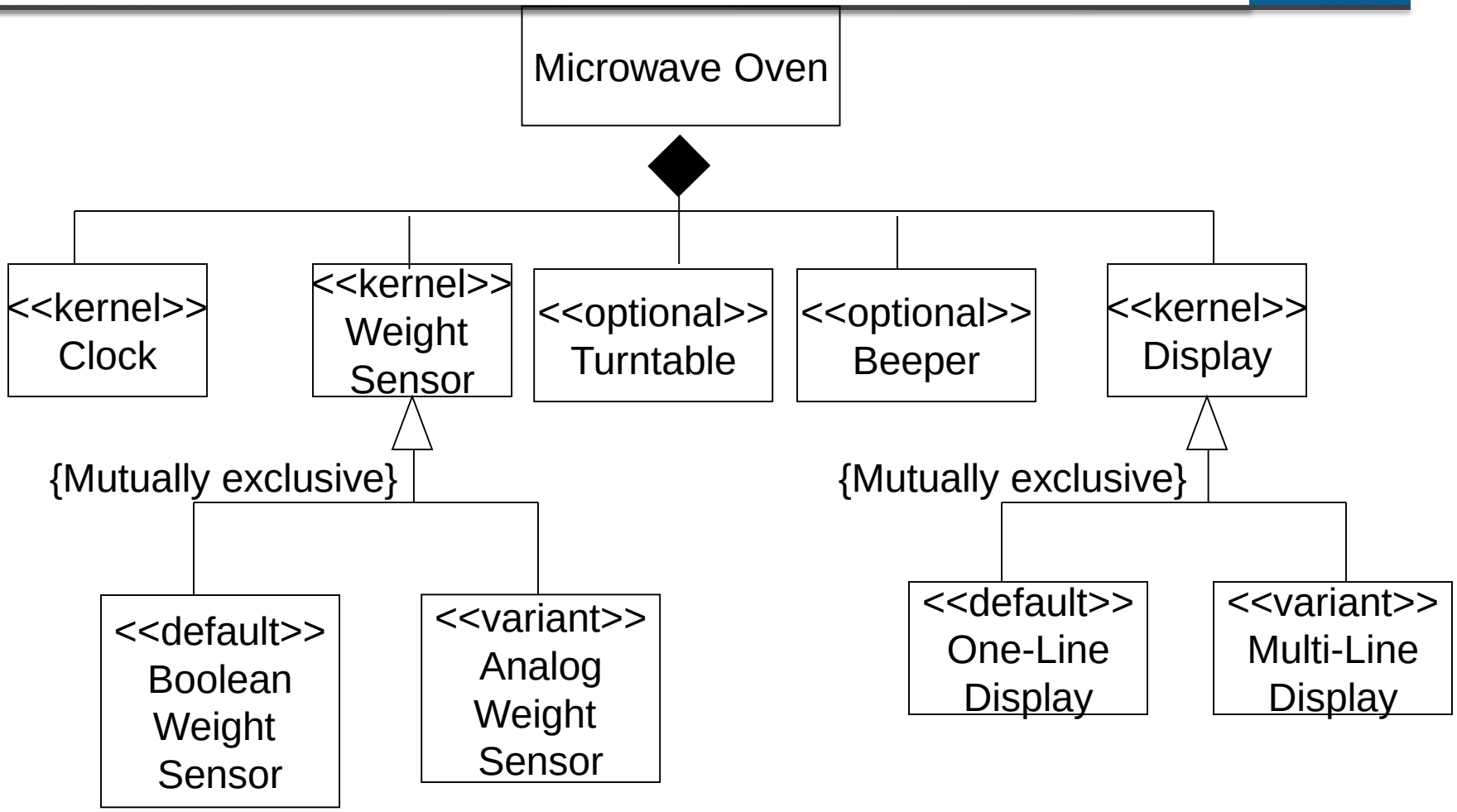
- ✧ Kernel UC
  - UC that are required by all members of the PL
- ✧ Optional UC
  - They are required by some, but not all the UC in the PL
- ✧ Alternative UC
  - Different versions of the UC are required by different members of the PL
  - They are usually mutually exclusive

PLUS Example: Use Cases



Adapted from [Gomaa05]

PLUS : Static Modeling



Adapted from [Gomaa05]

FeaturePlugin

- ✧ **Feature Modeling Plug-In for Eclipse**
- ✧ The tool supports
  - cardinality-based feature modeling
  - specialization of feature diagrams
  - configuration based on feature diagrams
- ✧ http://www.swen.uwaterloo.ca/~kczarnec/

- EShop Feature Model
  - Payment
    - PaymentTypes
      - CreditCard
      - DebitCard
      - PurchaseOrder
    - FraudDetection
  - Shipping
    - CustomMethods
      - [1..*] Method (String)
        - FlatRate (Float)
    - ShippingGateways
  - PasswordPolicy
    - Expiration
      - InDays (Integer)
      - Never
    - Chars
      - <2-4>
        - LowerCase
        - UpperCase
        - Digits
        - SpecialChars
  - EShop
    - ref: Payment
    - ref: Shipping
    - ref: PasswordPolicy

root symbol

obligatory

optional

The **group symbol** indicates group cardinality
1– *k*, where *k* is the group size.
Thus, our shop can support any non-empty subset of the three payment types.

Grouped features

group symbol indicates group cardinality of 1– 1

A feature can have an *attribute*, its type is indicated in parenthesis

- EShop
  - Payment
    - PaymentTypes
      - ☐ CreditCard
      - ☐ DebitCard
      - ☐ PurchaseOrder
    - ☐ FraudDetection
  - ☐ Shipping
    - ☐ CustomMethods
      - [0..*] Method (String)
        - FlatRate (Float)
      - Method ('FreeShipping' : String)
        - FlatRate ('0.0' : Float)
      - Method ('StandardShipping' : String)
        - FlatRate ('10.0' : Float)
    - ☐ ShippingGateways
  - PasswordPolicy
    - Expiration
      - ☐ InDays ('30' : Integer)
      - ☐ Never
    - Chars
      - <2-4>
        - ☐ LowerCase
        - ☐ UpperCase
        - ☐ Digits
        - ☐ SpecialChars

Key points

- There are many different ways to reuse software. These range from the reuse of classes and methods in libraries to the reuse of complete application systems.
- The advantages of software reuse are lower costs, faster software development and lower risks. System dependability is increased. Specialists can be used more effectively by concentrating their expertise on the design of reusable components.
- Software product lines are related applications that are developed from one or more base applications. A generic system is adapted and specialized to meet specific requirements for functionality, target platform or operational configuration.