Module 01

CHAPTER 1 SOFTWARE AND SOFTWARE ENGINEERING

CHAPTER 2 PROCESS MODELS

1.1 The Nature of Software

Software delivers the most important product of our time—information. It transforms personal data (e.g., an individual's financial transactions) so that the data can be more useful in a local context; it manages business information to enhance competitiveness; it provides a gateway to worldwide information networks (e.g., the Internet), and provides the means for acquiring information in all of its forms.

The role of computer software has undergone significant change over the last half-century. Dramatic improvements in hardware performance, profound changes in computing architectures, vast increases in memory and storage capacity, and a wide variety of exotic input and output options, have all precipitated more sophisticated and complex computer-based systems. Sophistication and complexity can produce dazzling results when a system succeeds, but they can also pose huge problems for those who must build complex systems.

1.1.1 Defining Software

Today, most professionals and many members of the public at large feel that they understand software. But do they?

A textbook description of software might take the following form:

Software is:

(1) instructions (computer programs) that when executed provide desired features, function, and performance;

(2) data structures that enable the programs to adequately manipulate information, and
(3) descriptive information in both hard copy and virtual forms that describes the operation and use of the programs.

Software has characteristics that are considerably different than those of hardware:

1. Software is developed or engineered; it is not manufactured in the classical sense
2. Software doesn't "wear out
3. Although the industry is moving toward component-based construction, most software continues to be custom built.

FIGURE 1.1
Failure curve for hardware

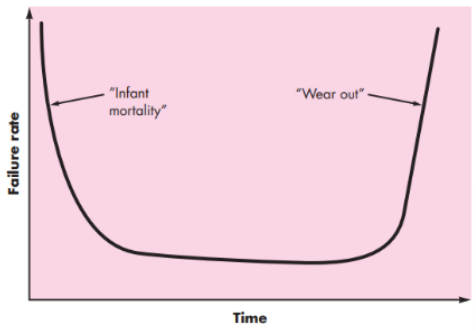
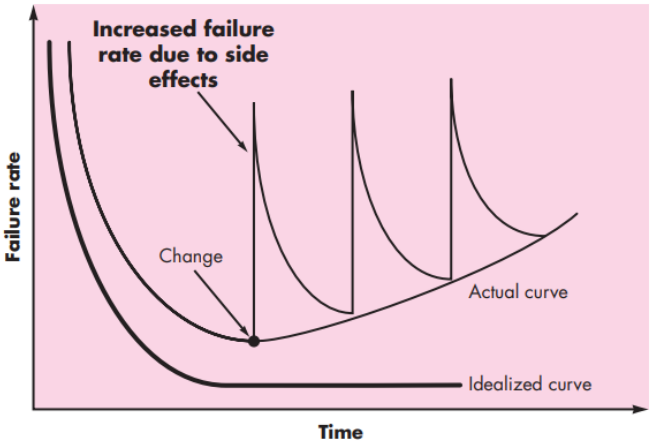


Figure 1.1 depicts failure rate as a function of time for hardware. The relationship, often called the "bathtub curve," indicates that hardware exhibits relatively high failure rates early in its life. Figure 1.1 depicts failure rate as a function of time for hardware. The relationship, often called the "bathtub curve," indicates that hardware exhibits relatively high failure rates early in its life (these failures are often attributable to design or manufacturing defects); defects are corrected and the failure rate drops to a steady-state level (hopefully, quite low) for some period of time. As time passes, however, the failure rate rises again as hardware components suffer from the cumulative effects of dust, vibration, abuse, temperature extremes, and many other environmental maladies. Stated simply, the hardware begins to wear out.

FIGURE 1.2
Failure curves for software



This seeming contradiction can best be explained by considering the actual curve in Figure 1.2. During its life,2 software will undergo change. As changes are made, it is likely that errors will be introduced, causing the failure rate curve to spike as shown in the "actual curve" (Figure 1.2). Before the curve can return to the original steady-state failure rate, another change is requested, causing the curve to spike again. Slowly, the minimum failure rate level begins to rise—the software is deteriorating due to change.

1.1.2 Software Application Domains

1. **System software:** system software is collection of programs written to service other programs. E.g. Compilers, editors, file management utilities, operating systems, drivers, networking etc.
2. **Application software:** Application software consists of standalone programs that solve a specific business need. E.g. Point of sole transaction processing, real time manufacturing control etc. -
3. **Engineering/scientific software**: Computer-aided design, system simulation, and other interactive applications have begun to take on real-time and even system software characteristics.
4. **Embedded software:** Embedded software resides within a product or system and is used to implement and control features and functions for the end-user and for the system itself. Embedded software can perform limited and esoteric functions. e.g. digital functions in an automobile such as fuel control, dashboard displays, braking systems, etc.
5. **Product-line software:** Designed to provide a specific capability for use by m any different customers product-line software can focus on a limited and esoteric marketplace or address mass consumer markets. e.g. inventory control, word processing, spreadsheets, computer graphics, multimedia etc.
6. (**Web applications):** "WebApps," span a wide array of applications. In their simplest form, webApps can be little more than a set of linked hypertext files that present information using text and limited graphics.
7. **AI software**: Al software makes use of non-numerical algorithms to solve complex problems that are not amenable to computation or straight forward analysis. e.g. robotics.

1.1.2 Legacy Software

Hundreds of thousands of computer programs fall into one of the seven broad application domains discussed in the preceding subsection. Some of these are stateof-the-art software—just released to individuals, industry, and government. But other programs are older, in some cases much older.

Legacy software systems . . . were developed decades ago and have been continually modified to meet changes in business requirements and computing platforms. The proliferation of such systems is causing headaches for large organizations who find them costly to maintain and risky to evolve.

Legacy systems often evolve for one or more of the following reasons:

- The software must be adapted to meet the needs of new computing environments or technology.
- The software must be enhanced to implement new business requirements.
- The software must be extended to make it interoperable with other more modern systems or databases.
- The software must be re-architected to make it viable within a network environment.

1.2 THE UNIQUE NATURE OF WEBAPPS

Characteristics of WebApps - I

- **Network intensiveness.** A WebApp resides on a network and must serve the needs of a diverse community of clients.
- **Concurrency.** A large number of users may access the WebApp at one time.
- **Unpredictable load.** The number of users of the WebApp may vary by orders of magnitude from day to day.
- **Performance.** If a WebApp user must wait too long (for access, for server-side processing, for client-side formatting and display), he or she may decide to go elsewhere.
- **Availability.** Although expectation of 100 percent availability is unreasonable, users of popular WebApps often demand access on a "24/7/365" basis.

Characteristics of WebApps - II

- **Data driven.** The primary function of many WebApps is to use hypermedia to present text, graphics, audio, and video content to the end-user.
- **Content sensitive.** The quality and aesthetic nature of content remains an important determinant of the quality of a WebApp.
- **Continuous evolution.** Unlike conventional application software that evolves over a series of planned, chronologically-spaced releases, Web applications evolve continuously.
- **Immediacy.** Although *immediacy*—the compelling need to get software to market quickly—is a characteristic of many application domains, WebApps often exhibit a time to market that can be a matter of a few days or weeks.
- **Security.** Because WebApps are available via network access, it is difficult, if not impossible, to limit the population of end-users who may access the application.
- **Aesthetics.** An undeniable part of the appeal of a WebApp is its look and feel.

These slides are designed to accompany Software Engineering: A Practitioner's Approach, 7/e

1.3 What is software engineering?

Your thoughts here

- Related to the process: a systematic procedure used for the analysis, design, implementation, test and maintenance of software.
- Related to the product: the software should be efficient, reliable, usable, modifiable, portable, testable, reusable, maintainable, interoperable, and correct

The definition in IEEE Standard:

- The application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software, that is, the application of engineering to software.
- The study of approaches as in 1993: The Joint IEEE Computer Society and ACM Steering Committee for the establishment of software engineering as a profession

1.4 The Software Process

A process is a collection of activities, actions, and tasks that are performed when some work product is to be created.

- An activity strives to achieve a broad objective (e.g., communication with stakeholders) and is applied regardless of the application domain, size of the project, complexity of the effort, or degree of rigor with which software engineering is to be applied.
- An action (e.g., architectural design) encompasses a set of tasks that produce a major work product (e.g., an architectural design model). A task focuses on a small, but well-defined objective (e.g., conducting a unit test) that produces a tangible outcome
- A process framework establishes the foundation for a complete software engineering process by identifying a small number of framework activities that are applicable to all software projects, regardless of their size or complexity.
- In addition, the process framework encompasses a set of umbrella activities that are applicable across the entire software process.
- A generic process framework for software engineering encompasses five activities
    - **Communication.** Before any technical work can commence, it is critically important to communicate and collaborate with the customer.
    - **Planning.** Any complicated journey can be simplified if a map exists. A software project is a complicated journey, and the planning activity creates a "map" that helps guide the team as it makes the journey
    - **Modeling**. Whether you're a landscaper, a bridge builder, an aeronautical engineer, a carpenter, or an architect, you work with models every day. You create a "sketch" of the thing so that you'll understand the big picture — what it will look like architecturally,
    - **Construction.** This activity combines code generation (either manual or automated) and the testing that is required to uncover errors in the code.
    - **Deployment**. The software (as a complete entity or as a partially completed increment) is delivered to the customer who evaluates the delivered product and provides feedback based on the evaluation.
- software engineering process framework activities are complemented by a number of umbrella activities.
- In general, umbrella activities are applied throughout a software project and help a software team manage and control progress, quality, change, and risk.
- Typical umbrella activities include:
    - **Software project tracking and control**—allows the software team to assess progress against the project plan and take any necessary action to maintain the schedule.
    - **Risk management**—assesses risks that may affect the outcome of the project or the quality of the product.
    - **Software quality assurance**—defines and conducts the activities required to ensure software quality.
    - **Technical reviews**—assesses software engineering work products in an effort to uncover and remove errors before they are propagated to the next activity.
    - **Measurement**—defines and collects process, project, and product measures that assist the team in delivering software that meets stakeholders' needs; can be used in conjunction with all other framework and umbrella activities
    - **Software configuration management**—manages the effects of change throughout the software process.

- **Reusability management**—defines criteria for work product reuse (including software components) and establishes mechanisms to achieve reusable components.
- **Work product preparation and production**—encompasses the activities required to create work products such as models, documents, logs, forms, and lists.

1.4 Software Engineering Practice

Generic software process model composed of a set of activities that establish a framework for software engineering practice. Generic framework activities—communication, planning, modeling, construction, and deployment—and umbrella activities establish a skeleton architecture for software engineering work. But how does the practice of software engineering fit in? In the sections that follow, you'll gain a basic understanding of the generic concepts and principles that apply to framework activities.

1.5.1 The Essence of Practice

In a classic book, How to Solve It, written before modern computers existed, George Polya [Pol45] outlined the essence of problem solving, and consequently, the essence of software engineering practice:

1. Understand the problem (communication and analysis).
2. Plan a solution (modeling and software design)
3. Carry out the plan (code generation).
4. Examine the result for accuracy (testing and quality assurance).

Understand the problem. It's sometimes difficult to admit, but most of us suffer from hubris when we're presented with a problem.

- Who has a stake in the solution to the problem? That is, who are the stakeholders?
- What are the unknowns? What data, functions, and features are required to properly solve the problem?
- Can the problem be compartmentalized? Is it possible to represent smaller problems that may be easier to understand?
- Can the problem be represented graphically? Can an analysis model be created?

Plan the solution. Now you understand the problem (or so you think) and you can't wait to begin coding. Before you do, slow down just a bit and do a little design:

- Have you seen similar problems before? Are there patterns that are recognizable in a potential solution? Is there existing software that implements the data, functions, and features that are required?
- Has a similar problem been solved? If so, are elements of the solution reusable?
- Can subproblems be defined? If so, are solutions readily apparent for the subproblems?
- Can you represent a solution in a manner that leads to effective implementation? Can a design model be created?

Carry out the plan. The design you've created serves as a road map for the system you want to build. There may be unexpected detours, and it's possible that you'll discover an even better route as you go, but the "plan" will allow you to proceed without getting lost.

- Does the solution conform to the plan? Is source code traceable to the design model?
- Is each component part of the solution provably correct? Have the design and code been reviewed, or better, have correctness proofs been applied to the algorithm?

Examine the result. You can't be sure that your solution is perfect, but you can be sure that you've designed a sufficient number of tests to uncover as many errors as possible.

- Is it possible to test each component part of the solution? Has a reasonable testing strategy been implemented?

• Does the solution produce results that conform to the data, functions, and features that are required? Has the software been validated against all stakeholder requirements?

1.5.2 General Principles

David Hooker [Hoo96] has proposed seven principles that focus on software engineering practice as a whole. They are reproduced in the following paragraphs:

1. The First Principle: The Reason It All Exists
2. The Second Principle: KISS (Keep It Simple, Stupid!)
3. The Third Principle: Maintain the Vision
4. The Fourth Principle: What You Produce, Others Will Consume
5. The Fifth Principle: Be Open to the Future
6. The Sixth Principle: Plan Ahead for Reuse
7. The Seventh principle: Think!

1.6 Software myths

Software myths—erroneous beliefs about software and the process that is used to build it—can be traced to the earliest days of computing. Myths have a number of attributes that make them insidious.

Management myths. Managers with software responsibility, like managers in most disciplines, are often under pressure to maintain budgets, keep schedules from slipping, and improve quality.

Myth: We already have a book that's full of standards and procedures for building software. Won't that provide my people with everything they need to know?

Reality: The book of standards may very well exist, but is it used? Are software practitioners aware of its existence? Does it reflect modern software engineering practice? Is it complete? Is it adaptable? Is it streamlined to improve time-to-delivery while still maintaining a focus on quality? In many cases, the answer to all of these questions is "no."

Myth: If I decide to outsource the software project to a third party, I can just relax and let that firm build it.

Reality: If an organization does not understand how to manage and control software projects internally, it will invariably struggle when it outsources software projects.

Customer myths. A customer who requests computer software may be a person at the next desk, a technical group down the hall, the marketing/sales department, or an outside company that has requested software under contract.

Myth: A general statement of objectives is sufficient to begin writing programs—we can fill in the details later.

Reality: Although a comprehensive and stable statement of requirements is not always possible, an ambiguous "statement of objectives" is a recipe for disaster. Unambiguous requirements (usually derived iteratively) are developed only through effective and continuous communication between customer and developer.

Practitioner's myths. Myths that are still believed by software practitioners have been fostered by over 50 years of programming culture. During the early days, programming was viewed as an art form. Old ways and attitudes die hard.

Myth: Once we write the program and get it to work, our job is done.

Reality: Someone once said that "the sooner you begin 'writing code,' the longer it'll take you to get done." Industry data indicate that between 60 and 80 percent of all effort expended on software will be expended after it is delivered to the customer for the first time.

CHAPTER 2 PROCESS MODELS

2.1 A Generic Process Model

- a generic process framework for software engineering defines five framework activities—communication, planning, modeling, construction, and deployment.
- In addition, a set of umbrella activities—project tracking and control, risk management, quality assurance, configuration management, technical reviews, and others—are applied throughout the process.

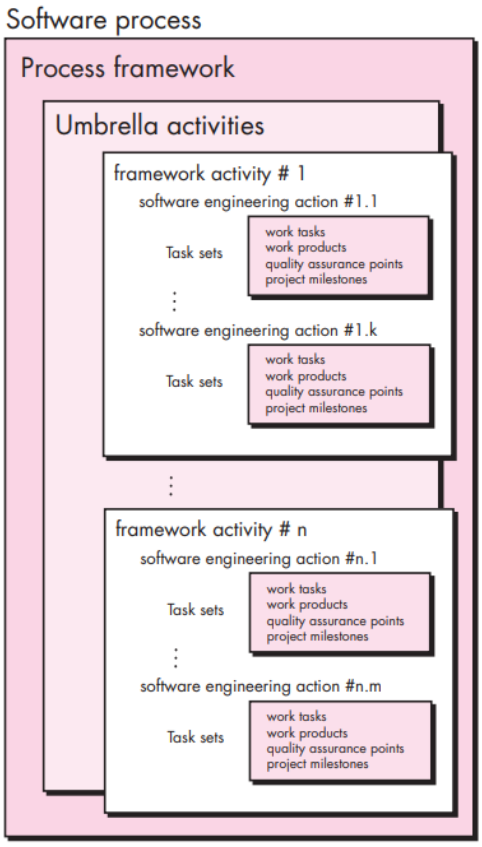
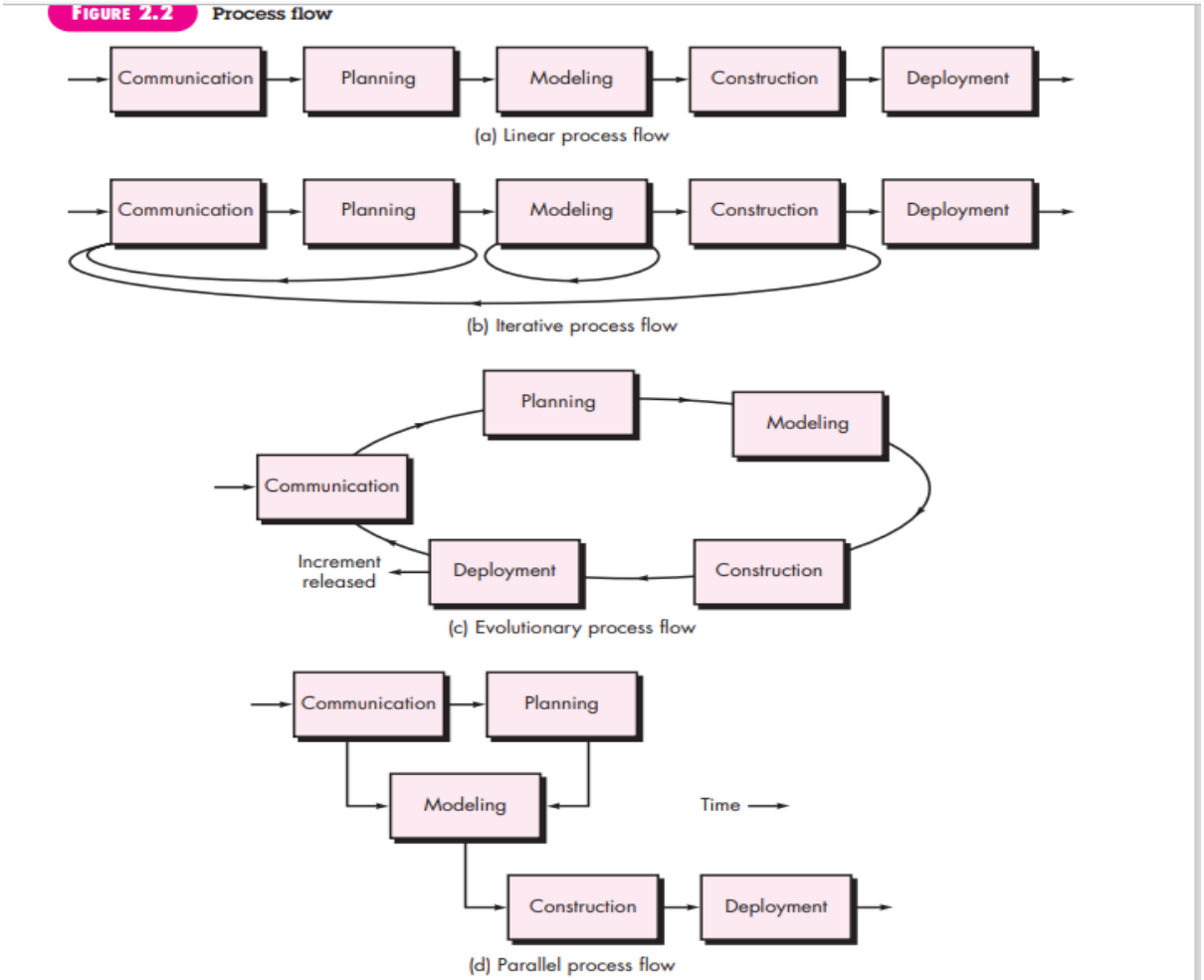


FIGURE 2.1 A software process framework

The software process is represented schematically in Figure 2.1. Referring to the figure, each framework activity is populated by a set of software engineering actions. Each software engineering action is defined by a task set that identifies the work tasks that are to be completed, the work products that will be produced, the quality assurance points that will be required, and the milestones that will be used to indicate progress.



A linear process flow executes each of the five framework activities in sequence, beginning with communication and culminating with deployment (Figure 2.2a).

An iterative process flow repeats one or more of the activities before proceeding to the next (Figure 2.2b).

An evolutionary process flow executes the activities in a "circular" manner. Each circuit through the five activities leads to a more complete version of the software (Figure 2.2c).

A parallel process flow (Figure 2.2d) executes one or more activities in parallel with other activities (e.g., modeling for one aspect of the software might be executed in parallel with construction of another aspect of the software).

2.1.1 Defining a Framework Activity

a software team would need significantly more information before it could properly execute any one of these activities as part of the software process. Therefore, you are faced with a key question: What actions are appropriate for a framework activity, given the nature of the problem to be solved, the characteristics of the people doing the work, and the stakeholders who are sponsoring the project?

For a small software project requested by one person (at a remote location) with simple, straightforward requirements, the communication activity might encompass little more than a phone

call with the appropriate stakeholder. Therefore, the only necessary action is phone conversation, and the work tasks (the task set) that this action encompasses are:

1. Make contact with stakeholder via telephone.
2. Discuss requirements and take notes. How does a framework activity change as the nature of the project changes?
3. Organize notes into a brief written statement of requirements.
4. E-mail to stakeholder for review and approval

2.1.2 Identifying a Task Set

Referring software process framework Figure 2.1, each software engineering action (e.g., elicitation, an action associated with the communication activity) can be represented by a number of different task sets—each a collection of software engineering work tasks, related work products, quality assurance points.

- A list of the task to be accomplished
- A list of the work products to be produced
- A list of the quality assurance filters to be applied

2.1.3 Process Patterns

- Ambler [Amb98] has proposed a template for describing a process pattern:
  - **Pattern Name**. The pattern is given a meaningful name describing it within the context of the software process (e.g., TechnicalReviews).
  - **Forces**. The environment in which the pattern is encountered and the issues that make the problem visible and may affect its solution.
  - **Type.** The pattern type is specified. Ambler [Amb98] suggests three types:
    - **Stage pattern**—defines a problem associated with a framework activity for the process. Since a framework activity encompasses multiple actions and work tasks, a stage pattern incorporates multiple task patterns (see the following) that are relevant to the stage (framework activity). An example of a stage pattern might be Establishing Communication. This pattern would incorporate the task pattern Requirements Gathering and others.
    - **Task pattern**—defines a problem associated with a software engineering action or work task and relevant to successful software engineering practice (e.g., Requirements Gathering is a task pattern).
    - **Phase pattern**—define the sequence of framework activities that occurs within the process, even when the overall flow of activities is iterative in nature. An example of a phase pattern might be Spiral Model or Prototyping.

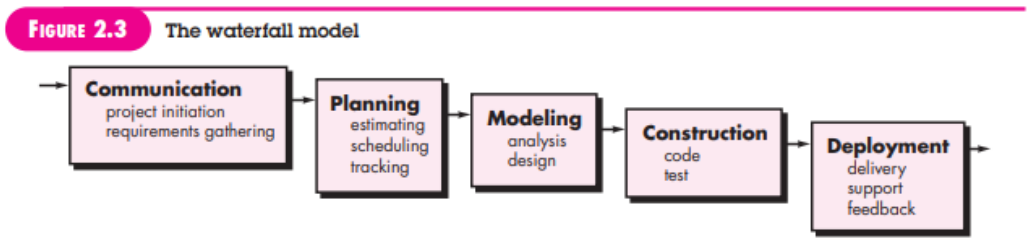
Process Assessment and Improvement

- **Standard CMMI Assessment Method for Process Improvement (SCAMPI)** — provides a five step process assessment model that incorporates five phases: initiating, diagnosing, establishing, acting and learning.
- **CMM-Based Appraisal for Internal Process Improvement (CBA IPI)** —provides a diagnostic technique for assessing the relative maturity of a software organization; uses the SEI CMM as the basis for the assessment [Dun01]
- **SPICE—The SPICE (ISO/IEC15504)** standard defines a set of requirements for software process assessment. The intent of the standard is to assist organizations in developing an objective evaluation of the efficacy of any defined software process. [ISO08]
- **ISO 9001:2000 for Software**—a generic standard that applies to any organization that wants to improve the overall quality of the products, systems, or services that it provides. Therefore, the standard is directly applicable to software organizations and companies. [Ant06]

2.3 PRESCRIPTIVE PROCESS MODELS

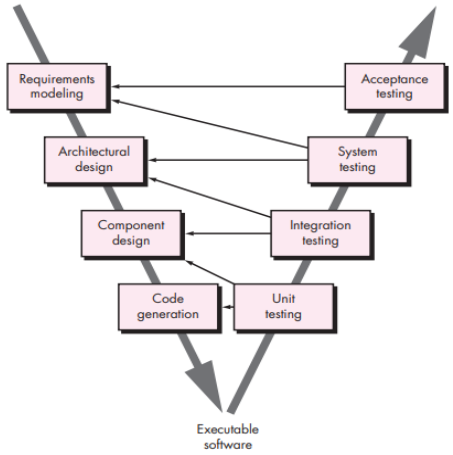
- Prescriptive process models advocate an orderly approach to software engineering.
    1. Waterfall model,
    2. Incremental process models,
    3. Evolutionary process models,
    4. Concurrent models,

2.3.1 Waterfall model



There are times when the requirements for a problem are well understood—when work flows from communication through deployment in a reasonably linear fashion. This situation is sometimes encountered when well-defined adaptations or enhancements to an existing system must be made (e.g., an adaptation to accounting software that has been mandated because of changes to government regulations). It may also occur in a limited number of new development efforts, but only when requirements are well defined and reasonably stable. The waterfall model, sometimes called the classic life cycle, suggests a systematic, sequential approach6 to software development that begins with customer specification of requirements and progresses through planning, modeling, construction, and deployment, culminating in ongoing support of the completed software (Figure 2.3)

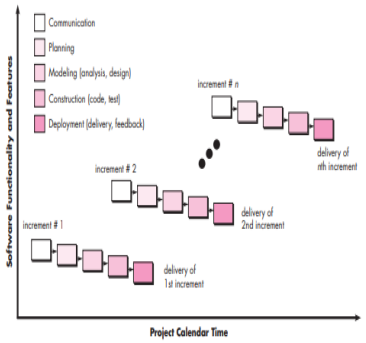
FIGURE 2.4
The V-model



A variation in the representation of the waterfall model is called the V-model. Represented in Figure 2.4, the V-model [Buc99] depicts the relationship of quality assurance actions to the actions associated with communication, modeling, and early construction activities. As a software team moves down the left side of the V, basic problem requirements are refined into progressively more detailed and technical representations of the problem and its solution. Once code has been generated, the team moves up the right side of the V, essentially performing a series of tests (quality assurance actions) that validate each of the models created as the team moved down the left side.7 In reality, there is no fundamental difference between the classic life cycle and the V-model. The V-model provides a way of visualizing how verification and validation actions are applied to earlier engineering work.

2.3.2 Incremental Process Models

FIGURE 2.5
The incremental model



Incremental Model is a process of software development where requirements divided into multiple standalone modules of the software development cycle. In this model, each module goes through the requirements, design, implementation and testing phases. Every subsequent release of the module adds function to the previous release. The process continues until the complete system achieved.

For example, word-processing software developed using the incremental paradigm might deliver basic file management, editing, and document production functions in the first increment; more sophisticated editing and document production capabilities in the second increment; spelling and grammar checking in the third increment; and advanced page layout capability in the fourth increment. It should be noted that the process flow for any increment can incorporate the prototyping paradigm.

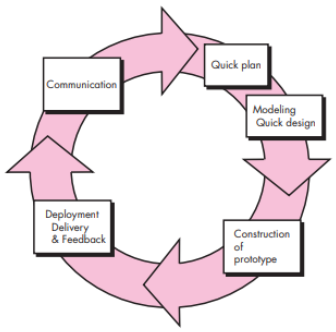
When an incremental model is used, the first increment is often a core product. That is, basic requirements are addressed but many supplementary features (some known, others unknown) remain undelivered. The core product is used by the customer (or undergoes detailed evaluation). As a result of use and/or evaluation, a plan is developed for the next increment. The plan addresses the modification of the core product to better meet the needs of the customer and the delivery of

additional features and functionality. This process is repeated following the delivery of each increment, until the complete product is produced.

2.3.2 Evolutionary Process Models

Prototyping. Often, a customer defines a set of general objectives for software, but does not identify detailed requirements for functions and features. In other cases, the developer may be unsure of the efficiency of an algorithm, the adaptability of an operating system, or the form that human-machine interaction should take. In these, and many other situations, a prototyping paradigm may offer the best approach

FIGURE 2.6
The prototyping paradigm

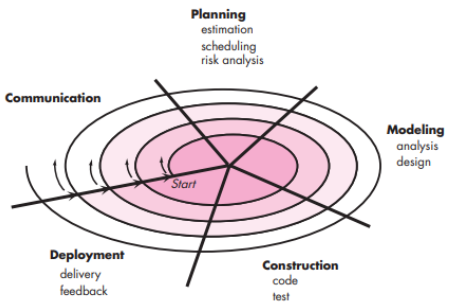


The prototyping paradigm (Figure 2.6) begins with communication. You meet with other stakeholders to define the overall objectives for the software, identify whatever requirements are known, and outline areas where further definition is mandatory. A prototyping iteration is planned quickly, and modeling (in the form of a "quick design") occurs. A quick design focuses on a representation of those aspects of the software that will be visible to end users (e.g., human interface layout or output display formats). The quick design leads to the construction of a prototype. The prototype is deployed and evaluated by stakeholders, who provide feedback that is used to further refine requirements. Iteration occurs as the prototype is tuned to satisfy the needs of various stakeholders, while at the same time enabling you to better understand what needs to be done.

Ideally, the prototype serves as a mechanism for identifying software requirements. If a working prototype is to be built, you can make use of existing program fragments or apply tools (e.g., report generators and window managers) that enable working programs to be generated quickly.

The Spiral Model. The spiral development model is a risk-driven process model generator that is used to guide multi-stakeholder concurrent engineering of software intensive systems. It has two main distinguishing features. One is a cyclic approach for incrementally growing a system's degree of definition and implementation while decreasing its degree of risk. The other is a set of anchor point milestones for ensuring stakeholder commitment to feasible and mutually satisfactory system solutions.

FIGURE 2.7
A typical spiral model



A spiral model is divided into a set of framework activities defined by the software engineering team. For illustrative purposes, I use the generic framework activities discussed earlier.9 Each of the framework activities represent one segment of the spiral path illustrated in Figure 2.7. As this evolutionary process begins, the software team performs activities that are implied by a circuit

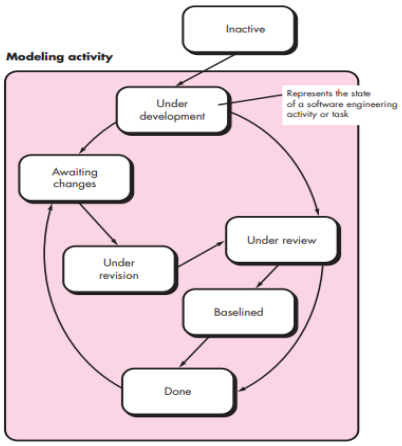
around the spiral in a clockwise direction, beginning at the center. Risk (Chapter 28) is considered as each revolution is made. Anchor point milestones—a combination of work products and conditions that are attained along the path of the spiral—are noted for each evolutionary pass.
The spiral model is a realistic approach to the development of large-scale systems and software. Because software evolves as the process progresses, the developer and customer better understand and react to risks at each evolutionary level. The spiral model uses prototyping as a risk reduction mechanism but, more important, enables you to apply the prototyping approach at any stage in the evolution of the product. It maintains the systematic stepwise approach suggested by the classic life cycle but incorporates it into an iterative framework that more realistically reflects the real world. The spiral model demands a direct consideration of technical risks at all stages of the project and, if properly applied, should reduce risks before they become problematic.

2.3.3 Concurrent Models

The concurrent development model

- The concurrent development model is called as concurrent model.
- The communication activity has completed in the first iteration and exits in the awaiting changes state.
- The modeling activity completed its initial communication and then go to the underdevelopment state.
- If the customer specifies the change in the requirement, then the modeling activity moves from the under development state into the awaiting change state.
- The concurrent process model activities moving from one state to another state

FIGURE 2.8
One element of the concurrent process model



Advantages of the concurrent development model

- This model is applicable to all types of software development processes.
- It is easy for understanding and use.
- It gives immediate feedback from testing.
- It provides an accurate picture of the current state of a project.

Disadvantages of the concurrent development model

- It needs better communication between the team members. This may not be achieved all the time.
- It requires to remember the status of the different activities.

2.4 SPECIALIZED PROCESS MODELS

2.4.1 Component-Based Development

Commercial off-the-shelf (COTS) software components, developed by vendors who offer them as products, provide targeted functionality with well-defined interfaces that enable the component to

be integrated into the software that is to be built. The component-based development model incorporates many of the characteristics of the spiral model. It is evolutionary in nature [Nie92], demanding an iterative approach to the creation of software. However, the component-based development model constructs applications from prepackaged software components Modeling and construction activities begin with the identification of candidate components.
These components can be designed as either conventional software modules or object-oriented classes or packages16 of classes. Regardless of the technology that is used to create the components, the component-based development model incorporates the following steps (implemented using an evolutionary approach):

1. Available component-based products are researched and evaluated for the application domain in question.
2. Component integration issues are considered.
3. A software architecture is designed to accommodate the components.
4. Components are integrated into the architecture.
5. Comprehensive testing is conducted to ensure proper functionality.

2.4.2 The Formal Methods Model

The formal methods model encompasses a set of activities that leads to formal mathematical specification of computer software. Formal methods enable you to specify, develop, and verify a computer-based system by applying a rigorous, mathematical notation.
A variation on this approach, called cleanroom software engineering is currently applied by some software development organizations. Although not a mainstream approach, the formal methods model offers the promise of defect-free software. Yet, concern about its applicability in a business environment has been voiced:

- The development of formal models is currently quite time consuming and expensive.
- Because few software developers have the necessary background to apply formal methods, extensive training is required.
- It is difficult to use the models as a communication mechanism for technically unsophisticated customers

2.4.3 Aspect-oriented software development

Aspect-oriented software development (AOSD), often referred to as aspect-oriented programming (AOP), is a relatively new software engineering paradigm that provides a process and methodological approach for defining, specifying, designing, and constructing aspects—"mechanisms beyond subroutines and inheritance for localizing the expression of a crosscutting concern".
Grundy [Gru02] provides further discussion of aspects in the context of what he calls aspect-oriented component engineering (AOCE)
AOCE uses a concept of horizontal slices through vertically-decomposed software components, called "aspects," to characterize cross-cutting functional and non-functional properties of components. Common, systemic aspects include user interfaces, collaborative work, distribution, persistency, memory management, transaction processing, security, integrity and so on. Components may provide or require one or more "aspect details" relating to a particular aspect, such as a viewing mechanism, extensible affordance and interface kind (user interface aspects); event generation, transport and receiving (distribution aspects); data store/retrieve and indexing (persistency aspects); authentication, encoding and access rights (security aspects); transaction atomicity, concurrency control and logging strategy (transaction aspects); and so on. Each aspect detail has a number of properties, relating to functional and/or non-functional characteristics of the aspect detail.