OBJECT ORIENTED SOFTWARE ENGINEERING (CAS775)

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OBJECT ORIENTED SOFTWARE ENGINEERING (CAS775)

Syllabus

- **Unit-I**: What is software engineering? Software Development Life Cycles Models, Conventional Software Life Cycle Models, What is Object Orientation? Objects and Classes, Features, Object Oriented Software Life Cycle Models, Object Oriented Methodologies, Object Oriented Modeling, Terminologies
- **Unit-II**: Software Requirements Elicitation and Analysis, Case Study: Library Management System What is Software Requirement? Requirements Elicitation Techniques, Characteristics of a good Requirement, Software Requirements Specification Document, Requirements Change Management, Object Oriented Analysis, Overview of Cost Estimation Techniques, Agile development, Classification of methods, The agile manifesto and principles, Agile project

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management, Agile Methodology, Method overview, Lifecycle, Work products, Roles and Practices values, Process mixtures, Adoption strategies, Understanding SCRUM

- **Unit-III**: Software Design, Object Oriented Design, What is done in object oriented design? UML, Refinement of Use Case Description, Refinement of classes and relationships, Construction of Details class diagrams, Development of Details Design and Creation, Generating Test cases from User Cases, Object Oriented Design principles for Improving Software Quality.

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- **Unit-IV**: Software Implementation- Quality and Metrics, Software Implementation Tools and Techniques, What is software quality? Software quality models, Measurement basic, analyzing the metric data, Metrics for measuring size and structure, Measuring software quality object oriented metrics, Overview of Scala for Implementation.
- **Unit-V**: Software Testing and Maintenance, What is software testing? Software verification techniques, Checklist: a popular verification tool, Functional Testing, Structural Testing, Object Oriented Testing, Class testing, State based testing, Mutation testing, Levels of testing, Software testing tools, What is a software maintenance? Categories, Challenges of software maintenance, Maintenance of Object oriented Software, Software rejuvenation, Estimation of maintenance efforts, Configuration management, Regression testing.

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- **References**:

1. Yogesh Singh, Ruchika Malhotra, "Object-Oriented Software Engineering", PHI, 2012.
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OBJECT ORIENTED SOFTWARE ENGINEERING (CAS775)

Outline

- Introduction to Software Engineering
- Software Development Life Cycle (SDLC)
- Object Orientation
- Object Oriented Software Life Cycle Models
- Object Oriented Methodologies

What is a Software?

- Computer programs (which are stored in and executed by computer hardware) and associated data (which also is stored in the hardware) that may be dynamically written or modified during execution. - National Institute of Standards and Technology (NIST), USA

What is a Software?

- Indispensable technology for business, science, and engineering.
- Enable the creation of new technologies for e.g., genetic engineering, and nanotechnology.
- Enable extension of existing technologies for e.g., telecommunications.
- Brought radical changes in older technologies for e.g., the printing industry.
- Driving force for personal computer revolution.

What is a Software?

- It is a product (delivers computing potential), and at the same time, the vehicle for delivering the product (basis for the control of computer, the communication of information, and the creation and control of other programs).
- An **information transformer** - producing, managing, acquiring, modifying, displaying, or transmitting information.

What does Software Engineer do?

- Solve problems economically by developing high-quality software.
- Software engineers design software systems.

Characteristics of Software

- Software is intangible.
  - One cannot feel the shape of a piece of software.
  - Software design can be hard to visualize.
- The mass-production of duplicate pieces of software is trivial.
  - Software is developed or engineered; it is not manufactured.
  - Cost of software is in its development, not its manufacturing.
- The software industry is labor intensive.
  - Require truly "intelligent" machines to fully automate software design or programming (very little success is achieved till date).
- Detection of bugs (errors or defects) is not so easy.
- Software is physically easy to modify; however, because of its complexity it is very difficult to make changes that are correct.
- Software does not wear out with use, but instead its design deteriorates as it is changed repeatedly.

Characteristics of Software

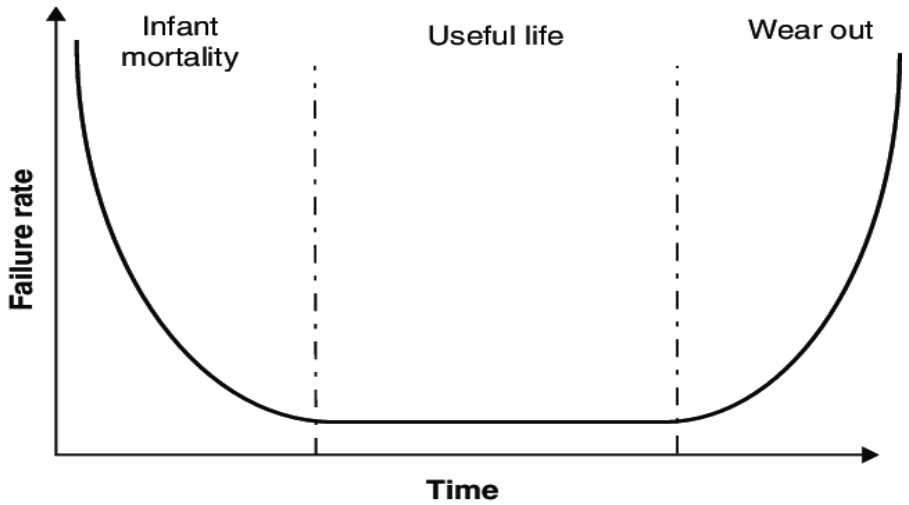


Figure : Failure Curve for Hardware

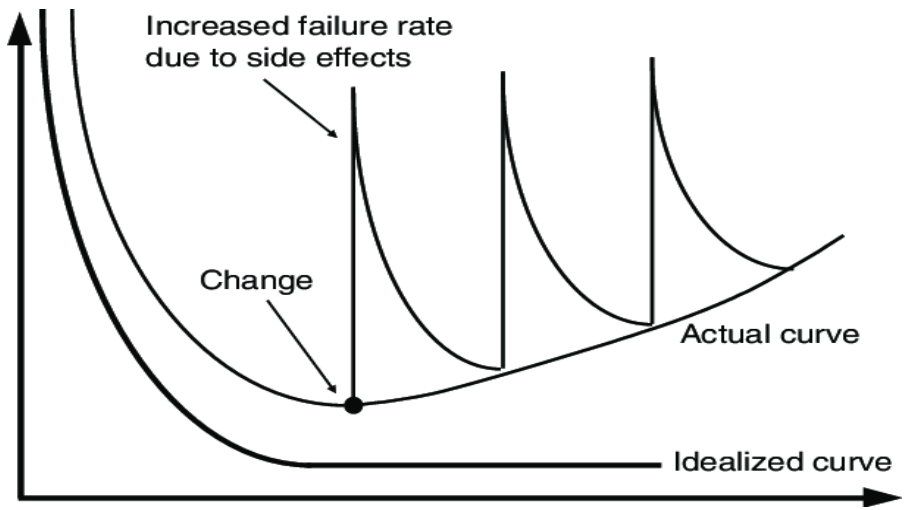


Figure : Failure Curve for Software

Software Application Domains

1. **System Software**
   - A collection of programs written to service other programs.
   - E.g., Operating System, drivers, compilers, networking softwares, file management utilities, etc.
   - Characteristics:
     - Heavy interaction with computer hardware
     - Heavy usage by multiple users
     - Concurrent operations (require scheduling, resource sharing, and sophisticated process management).
     - Complex data structures
     - Multiple external interfaces

Software Application Domains

2. **Application Software**
   - Stand alone programs that solve a specific business need.
   - Process business or technical data in a way that facilitate business operations or management/technical decision making.
   - Used to control business functions in real-time (e.g., point-of-sale transaction processing, real-time manufacturing process control).
3. **Engineering/Scientific Software**
   - Characterized by "number crunching" algorithms
   - **Applications**: austronomy, volcanology, space shuttle orbital dynamics, molecular biology, automated manufacturing, etc.

Software Application Domains

4. **Embedded Software**
   - Resides within a product or system.
   - Can perform limited and esoteric functions.
   - Used to implement and control features and functions for the end user and for the system itself.
5. **Product-line Software**
   - Designed to provide a specific capability for use by many different customers.
   - Can focus on a limited and esoteric marketplace (e.g., inventory control products) or address mass consumer products.

Software Application Domains

6. **Web Applications (WebApps)**
   - Network centric software category.
   - With the emergence of Web 2.0, WebApps evolved as sophisticated computing environments.
7. **Artificial Intelligence Software**
   - Uses nonnumerical algorithms to solve complex problems that are not amenable to computation or straightforward analysis.
   - **Applications**: Robotics, expert systems, pattern recognition (image and voice), etc.

Factors contributing to Software Crisis

- Existing softwares are of poor quality and repeated changes (because of strong demand for new and changed software) further deteriorates the quality.
- Late delivery and over budgeting of developed software.
- Already delivered software systems require major modification before they can be actually used.

Types of software

1. **Custom software**
   - Developed to meet the specific needs of a particular customer (of little use to others).
   - Typically used by only a few people and its success depends on meeting their needs.
   - Examples - web sites, air-traffic control systems and software for managing the specialized finances of large organizations, etc.
   - Comes under conventional projects(1960 - 1970, 100% custom built).

Types of software

2. **Generic software**
   - Designed to be sold on the open market, to perform functions that many people need, and to run on general purpose computers.
   - Requirements are determined largely by market research.
   - Often called Commercial Off-The-Shelf software (COTS).
   - Examples - word processors, spreadsheets, compilers, web browsers, operating systems, computer games and accounting packages for small businesses, etc.

Types of software

3. **Embedded software**
   - Runs on specific hardware devices which are typically sold on the open market.
   - Examples - washing machines, DVD players, microwave ovens, automobiles, etc.
   - Users cannot usually replace embedded software or upgrade it without also replacing the hardware.

Other categories of software

1. **Real-time Software**
   - Has to react immediately (i.e. in real time) to stimuli from the environment.
   - **Design criteria**: responsiveness must be always guaranteed.
   - All embedded systems operate in real time (with the use of special-purpose hardware).
   - Generic applications, such as spreadsheets and computer games - have soft real-time characteristics.
   - **Key concern**: safety

   1.1 **Hard Real-time System**: within a fraction of delay system will collapse for e.g., Air Traffic Control.

   1.2 **Soft Real-time System**: within a fraction of delay system will not collapse immediately, instead there will be some deterioration in functionality.

Other categories of software

2. **Data Processing Software**
   - Used to run businesses and performs functions such as recording sales, managing accounts, printing bills etc.
   - **Design issue**: organization of data in order to provide useful information to the users so they can perform their work effectively.
   - **Key concern**: accuracy and security of the data.

What is software engineering?

Software engineering is the process of solving customers problems by the systematic development and evolution of large, high-quality software systems within cost, time and other constraints.

Stakeholders in software engineering

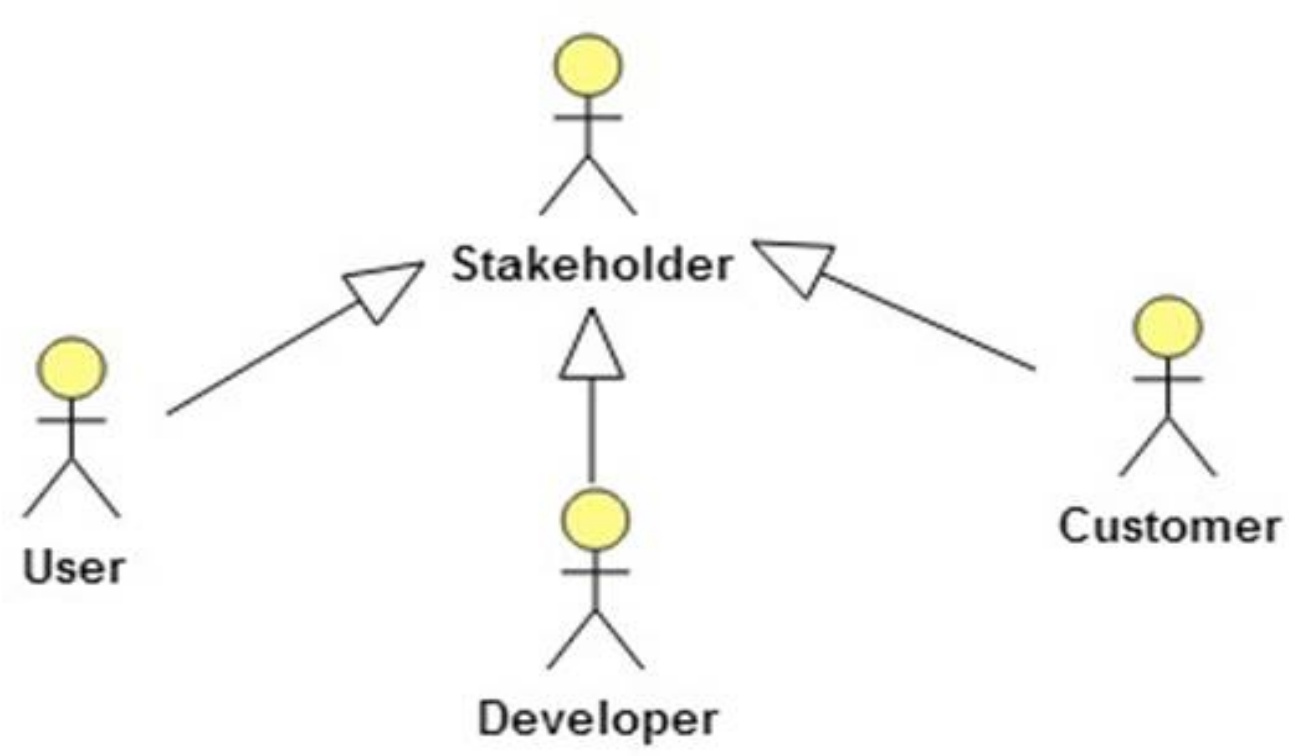


Figure : Stakeholders

Software quality

For a stakeholder, a software is said to be of good quality if the outcome of its development and maintenance helps them meet their personal objectives.

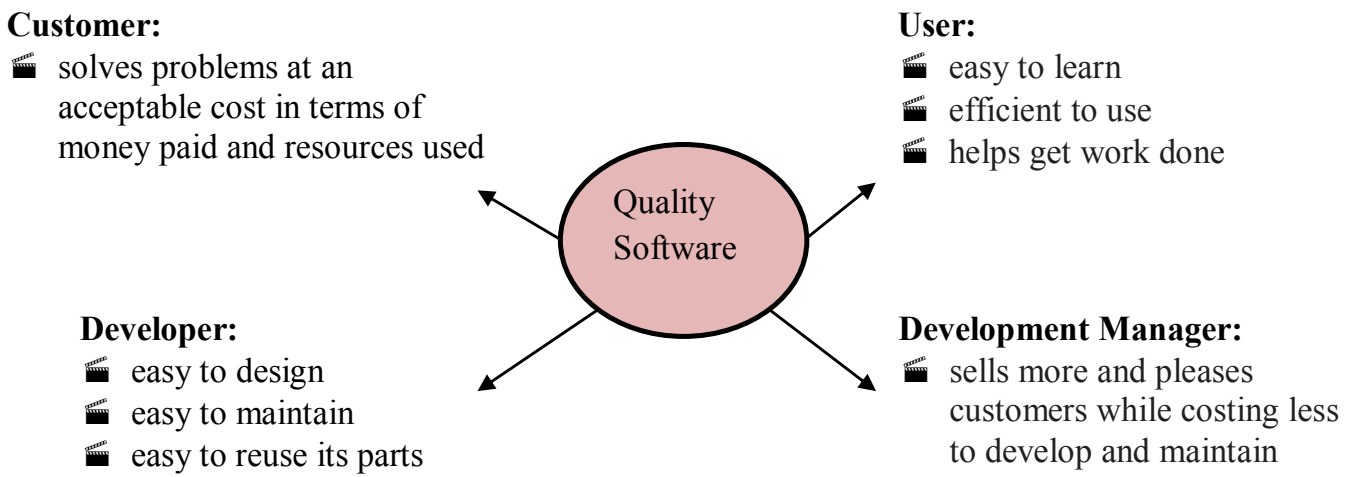


Figure : What software quality means to different stakeholders

Attributes of software quality

- **Usability**
  - User friendliness (learn, understand, and use)
  - The higher the usability of software, the easier it is for users to work with it.
  - **Aspects of usability**: learnability for novices, efficiency of use for experts, and handling of errors.
- **Efficiency**
  - The more efficient software is, the less it uses of CPU-time, memory, disk space, network bandwidth and other resources.
  - Customer is always concerned about the software efficiency.
- **Reliability**
  - Software is more reliable if it has fewer failures.
  - Reliability depends on the number and type of mistakes a software engineer make.

Question: An organization has developed a scientific application for a client. This application has 45 minute failure in a year. Calculate the reliability of this product?

Attributes of software quality

- **Maintainability**
  - Refers to the ease with which software engineer can change the software.
  - Software that is more maintainable can result in reduced costs for both developers and customers.
- **Reusability**
  - A software component is reusable if it can be used in several different systems with little or no modification.
  - High reusability can reduce the long-term costs faced by the development team.

- **Note:** These external software quality attributes can be observed by the stakeholders and have a direct impact on them.

Software quality trade-offs

- Improving efficiency may make a design less easy to understand. This can reduce maintainability, which leads to defects that reduce reliability.
- Achieving high reliability often involves repeatedly checking for errors and adding redundant computations; achieving high efficiency, in contrast, may require removing such checks and redundancy.
- Improving usability may require adding extra code to provide feedback to the users, which might in turn reduce overall efficiency and maintainability.

Internal software quality criteria

- **The amount of commenting of the code**
  - This can be measured as the fraction of total lines in the source code that are comments.
  - This impacts maintainability, and indirectly it impacts reliability.
- The complexity of the code measured in terms of the nesting depth, the number of branches and the use of certain complex programming constructs.
  - This directly impacts maintainability and reliability.

Categories of software engineering projects

1. **Evolutionary projects**
   - Projects that involve modifying an existing system.
   - Evolutionary or maintenance projects can be of several different types:
     - **Corrective projects**: involve fixing defects.
     - **Adaptive projects**: involve changing the system in response to changes in the environment in which the software runs.
     - **Enhancement projects**: involve adding new features for the users.
     - **Re-engineering or perfective projects**: involve changing the system internally so that it is more maintainable, without making significant changes that the user will notice.

Categories of software engineering projects

2. **Greenfield projects**
   - Projects that involve starting to develop a system from scratch.
   - Comes under conventional projects (1960 - 1970, 100% custom built).
3. Projects that involve building most of a new system from existing components, while developing new software only for missing details.
   - Modern Projects (2000 and onward, 70% reusable components, 30% custom built).

Ethics in Software Engineering

IEEE/ACM code of ethics

Software engineers shall:

- Act consistently with the public interest.
- Act in the best interests of their client or employer, as long as this is consistent with the public interest.
- Develop and maintain their product to the highest standards possible.
- Maintain integrity and independence when making professional judgments.
- Promote an ethical approach in management.
- Advance the integrity and reputation of the profession, as long as doing so is consistent with the public interest.
- Be fair and supportive to colleagues.
- Participate in lifelong learning.

Activities common to software projects

1. **Requirements and specification**

   Goal: understand the customer's problems, the customer's business environment, and the available technology which can be used to solve the problems.
   This overall process may include the following activities:

   1.1 **Domain Analysis**: understanding the background needed in order to understand the problem and make intelligent decisions.

   1.2 **Defining the problem**: narrowing down the scope of the system by determining the precise problem that needs to solved.

   1.3 **Requirements gathering**: obtaining all the ideas people have about what the software should do.

   1.4 **Requirements analysis**: organizing the information that has been gathered, and making decisions about what in fact the software should do.

   1.5 **Requirements specification**: writing a precise set of instructions that define what the software should do (only software behavior not implementation).

Activities common to software projects

2. **Design**: process of deciding how the requirements should be implemented using the available technology.
   Important activities during design include:
   - 2.1 **System Engineering**: deciding what requirements should be implemented in hardware and what in software.
   - 2.2 **Software architecture**: deciding how the software is to be divided into subsystems and how the subsystems are to interact (with the help of architectural patterns or styles).
   - 2.3 **Detailed design**: deciding how to construct the details of each subsystem. Such details include the data structures, classes, algorithms and procedures.
   - 2.4 **User interface design**: deciding in detail how the user is to interact with the system, and the look and feel of the system.
   - 2.5 **Database selection**: deciding how the data will be stored on disk in databases or files.

Activities common to software projects

3. **Modeling**: process of creating a representation of the domain or the software.

   Note: Modeling can be performed visually, using diagrams, or else using semi-formal or formal languages that express the information systematically or mathematically.

   Example: Unified Modeling Language (UML) - a visual language that uses semi-formal notations and diagrams.

   Various modeling approaches used during both requirements analysis and design are as follows:

   3.1 **Use case modeling**: representing the sequences of actions performed by the users of the software.

   3.2 **Structural modeling**: representing the classes and objects present in the domain or in the software.

   3.3 **Dynamic and behavioral modeling**: representing the states that the system can be in, the activities it can perform, and how its components interact.

Activities common to software projects

4. **Programming**
   - Involves the translation of higher-level designs into particular programming languages.
   - Final stage of design and it involves making decisions about the appropriate use of programming language constructs.
5. **Quality assurance (QA)**: include all the processes needed to ensure that the quality objectives of the software being developed are met.
   Quality assurance occurs throughout a project, and includes many activities, including the following:
   - 5.1 **Reviews and inspections**: formal meetings organized to discuss requirements, designs or code to see if they are satisfactory.
   - 5.2 **Testing**: process of systematically executing the software to see if it behaves as expected.

Activities common to software projects

6. **Deployment**
   - Involves distributing and installing the software and any other components of the system such as databases, special hardware etc.
   - It also involves managing the transition from any previous system.
7. **Managing software configurations**
   - Involves identifying all the components that compose a software system, including files containing requirements, designs and source code.
   - It also involves keeping track of these as they change, and ensuring that changes are performed in an organized way.

Activities common to software projects

8. **Managing the process**: integral part of software engineering. In addition to leading the other activities (described above), the manager has to undertake the following tasks:
   - 8.1 **Estimating the cost of the system**: involves studying the requirements and determining how much effort they will take to design and implement.
   - 8.2 **Planning**: process of allocating work to particular developers, and setting a schedule with deadlines.

   Note: Both cost estimates and plans need to be examined and revised on a regular basis, since initial estimates will only be rough.

Software Engineering Layers

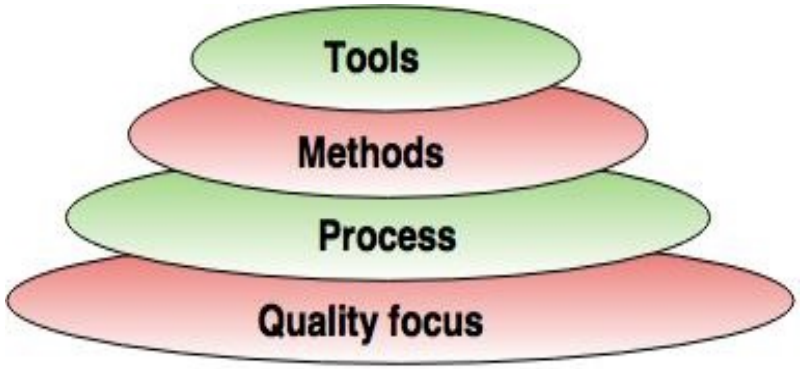


Figure : Software Engineering a layered technology

- **Quality Focus**: the bedrock that support software engineering (organizational commitment to quality).
- **Process**: the foundation of software engineering. Process defines a framework that must be established for effective delivery of software engineering technology.
- **Methods**: provide the technical how-to's for building software. Include broad array of tasks: communication, requirement analysis, design modeling, program construction, testing, and support.
- **Tools**: provide automated and semiautomated support for the process and the methods.

Software Process

Software Process: a framework for the activities, actions, and tasks that are required to build high-quality software.

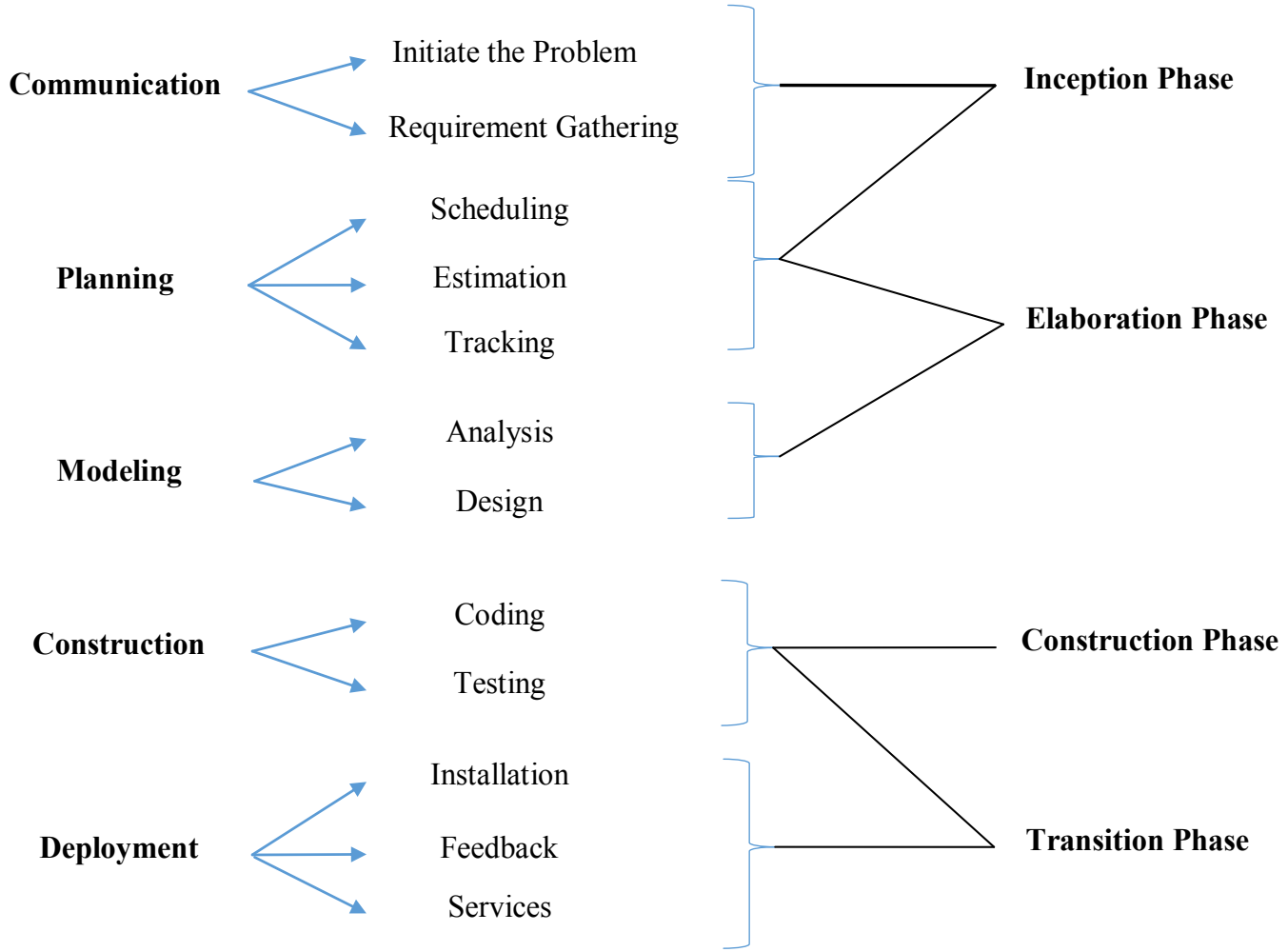


Figure : Activities of a generic Software Process framework

Software Process

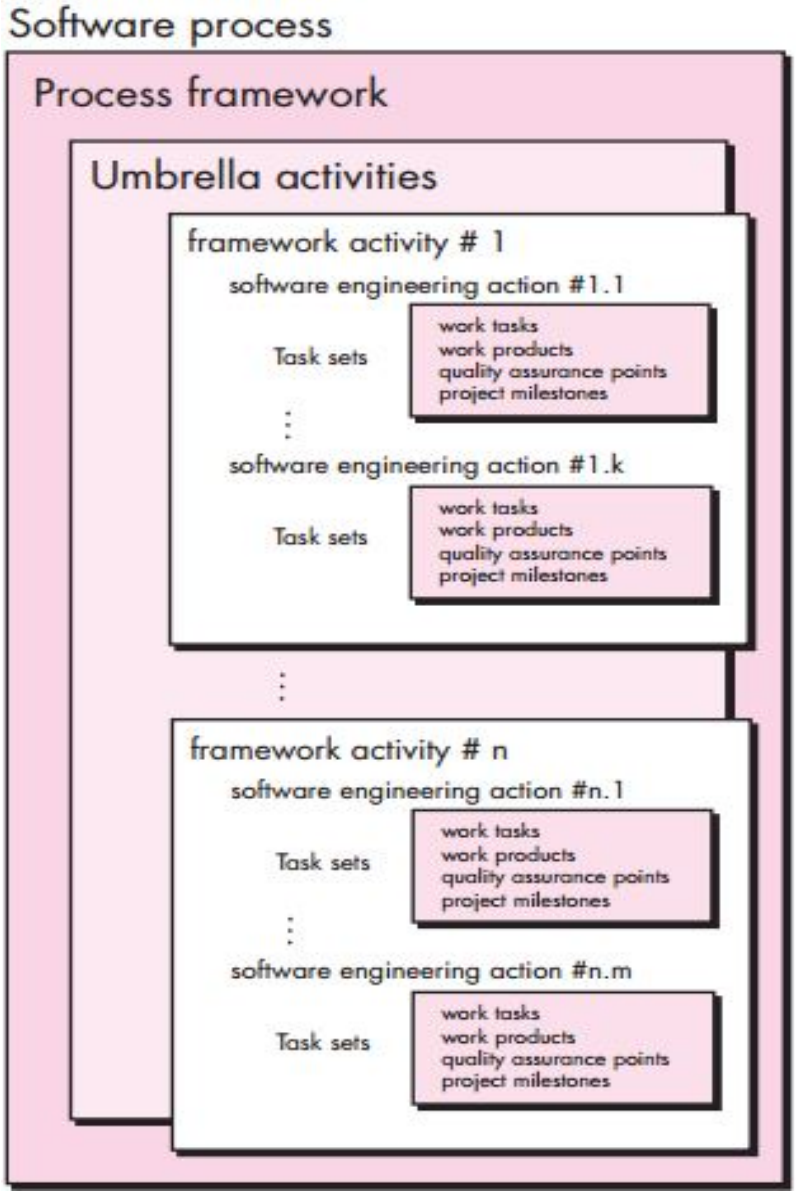


Figure : A software process framework

Process Flow

Process Flow: describes "how the framework activities and the actions and tasks that occur within each framework activity are organized with respect to the sequence and time".

Types of Process Flow

- **Linear process flow**: executes each of the five framework activities in sequence, beginning with communication and culminating with deployment.

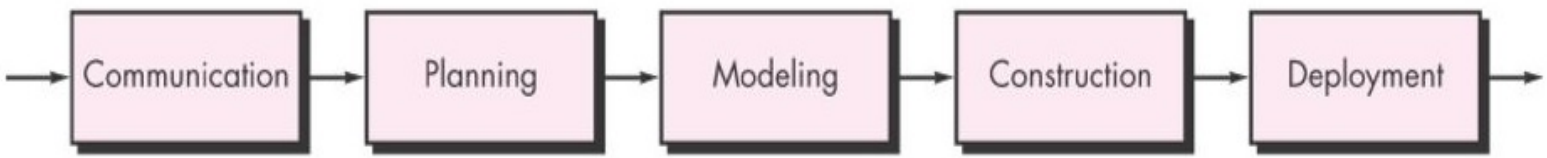


Figure : Linear process flow

Process Flow

Types of Process Flow

- **Iterative process flow**: repeats one or more of the activities before proceeding to the next.

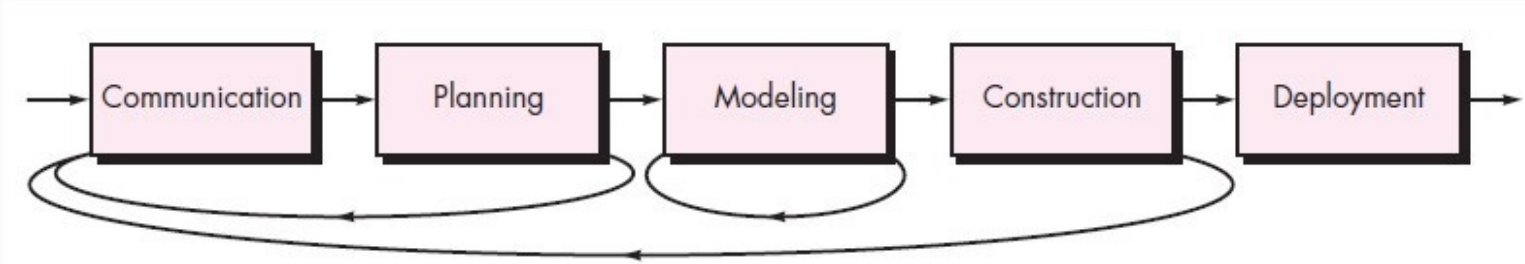


Figure : Iterative process flow

- **Evolutionary process flow**: executes the activities in a "circular" manner. Each circuit through the five activities leads to the more complete version of the software.

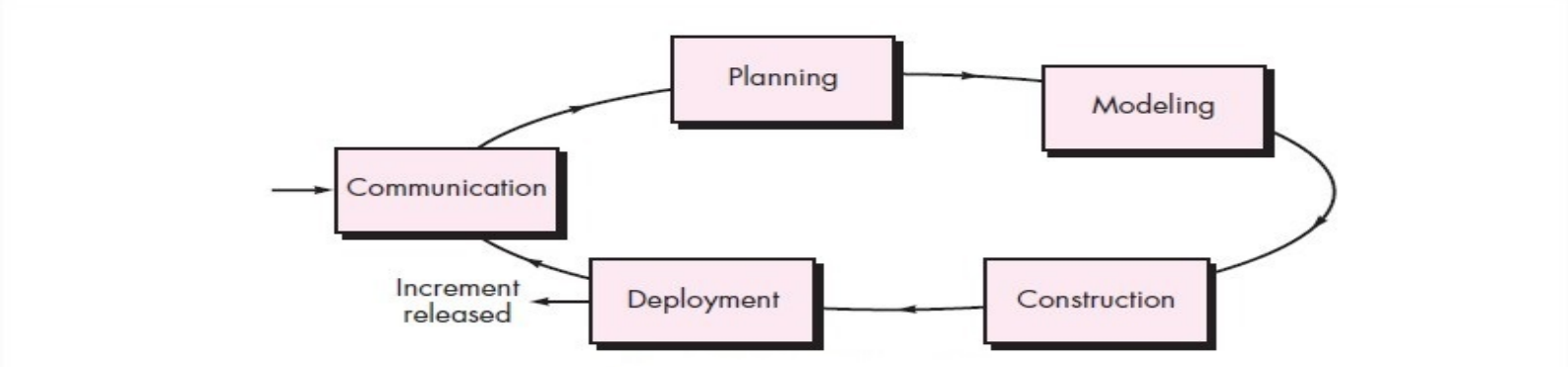


Figure : Evolutionary process flow

Process Flow

Types of Process Flow

- **Parallel process flow**: 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).

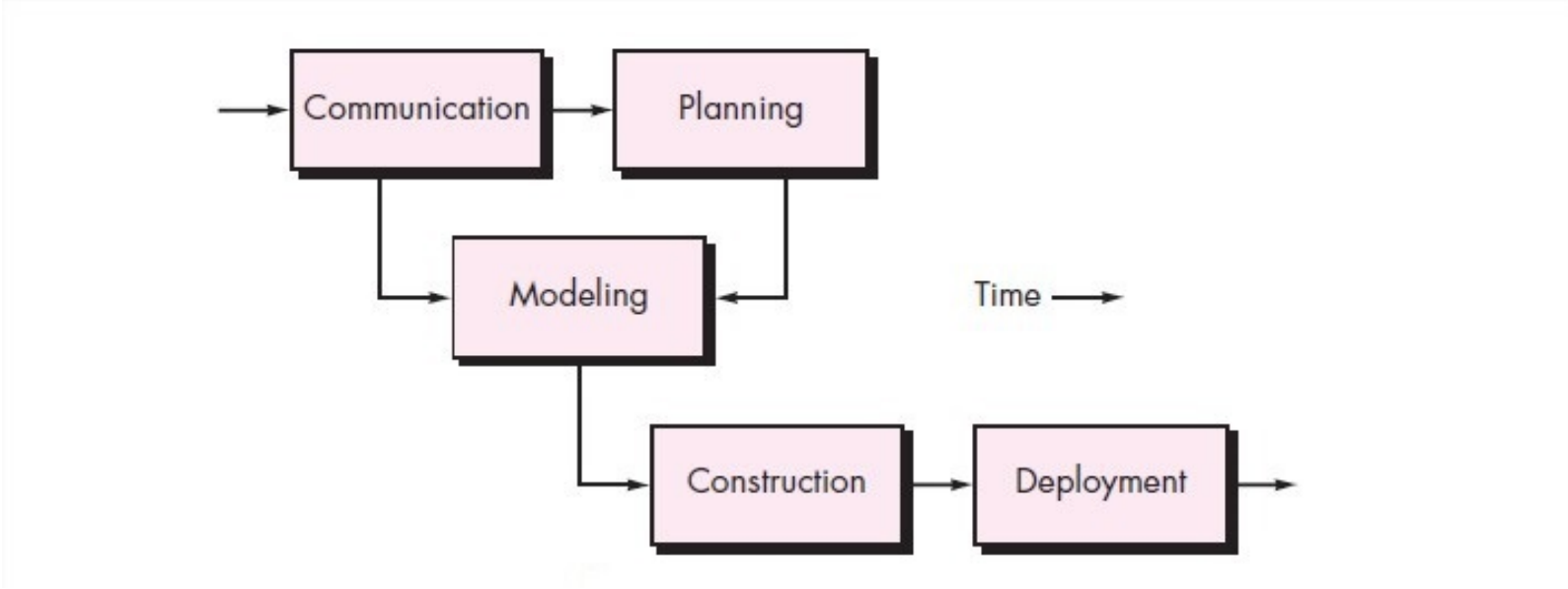


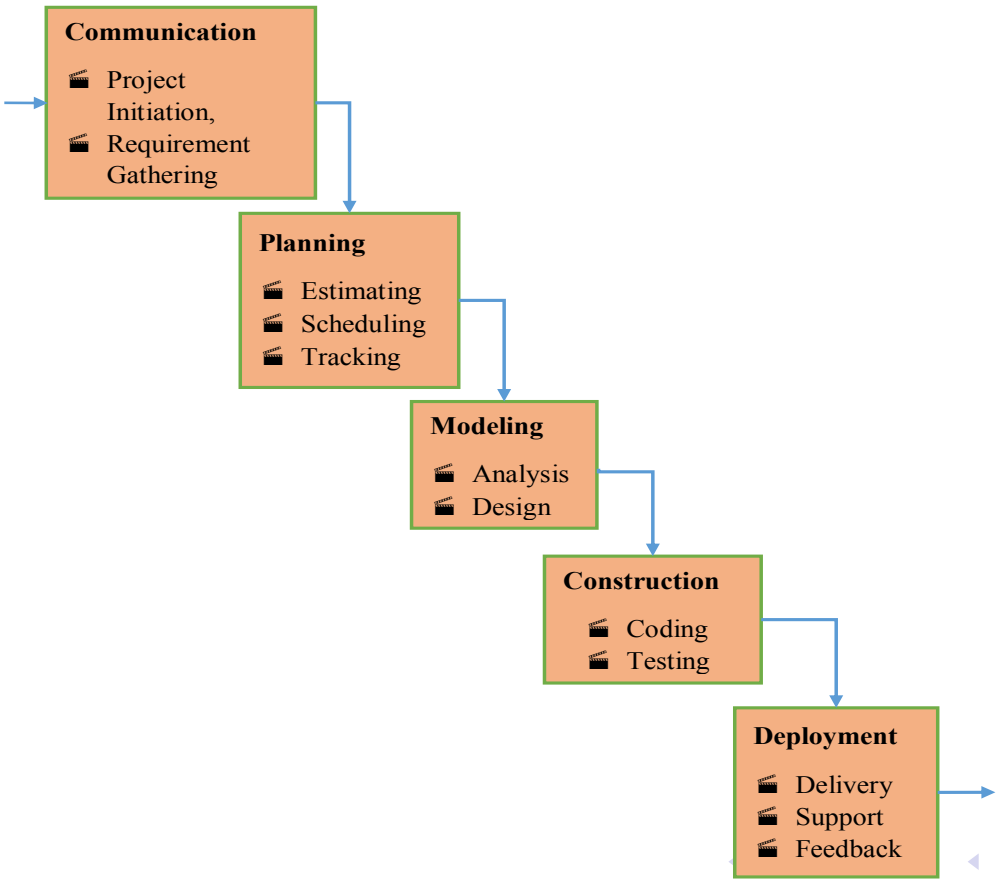
Figure : Parallel process flow

What is Process Model?

- Roadmap/guidelines for
  - Software development
  - Software maintenance
- Without using process model one can not
  - achieve quality
  - achieve continuous improvement
  - estimate resources
  - control process engineering activities

Process Model

- **The Waterfall Model**
  - Systematic, sequential approach 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.



Process Model

- **The Waterfall Model**
  - Also called as classic life cycle model or Royce model (proposed by Winston Royce in 1970) or linear sequential process model.
  - Ideal in situation where requirements are fixed and work is to proceed to completion in a linear fashion.
  - Document driven approach (customer has to state all the requirements explicitly).
  - A working version of the program(s) will not be available until late in the project time span, i.e., only core/final product will be delivered to customer at the end.
  - Suffers from blocking state problem.

Process Model

- **Incremental Process Model**
  - **Motivation**: compelling need to provide a limited set software functionality (core product with minimal features) to users quickly.
  - Incremental process model produce the software in increments (pilot approach).
  - Incremental process model combines elements of linear and parallel process flows.

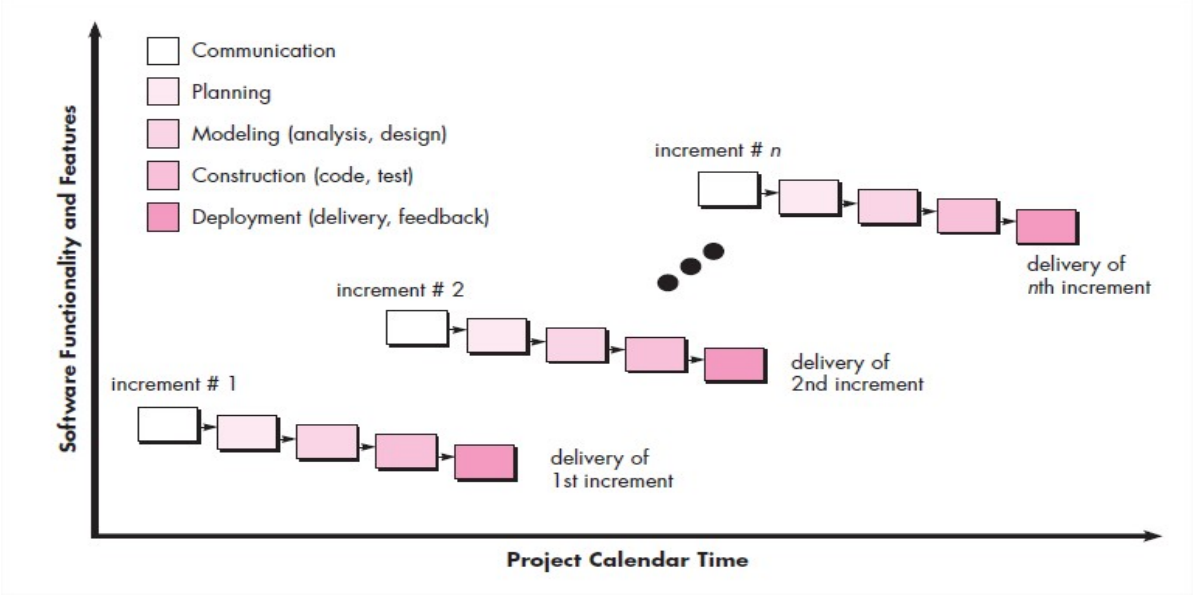


Figure : The incremental model

Process Model

- **Evolutionary Process Model**
  - **Motivation**: a set of core product or system requirements is well understood, but the details of product or system extensions have yet to be defined.
  - Evolutionary process models are explicitly designed to accommodate a product that evolves over time.
  - Evolutionary process models are iterative in nature.
  - Types of evolutionary process models:
    1. **Prototyping**
    2. **The Spiral Model**

Process Model

- **Prototyping**
  - **Motivation**: used when the requirements are fuzzy.
    - Customer defines a set of general objectives for software, but does not identify detailed requirements for functions and features.
    - 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.

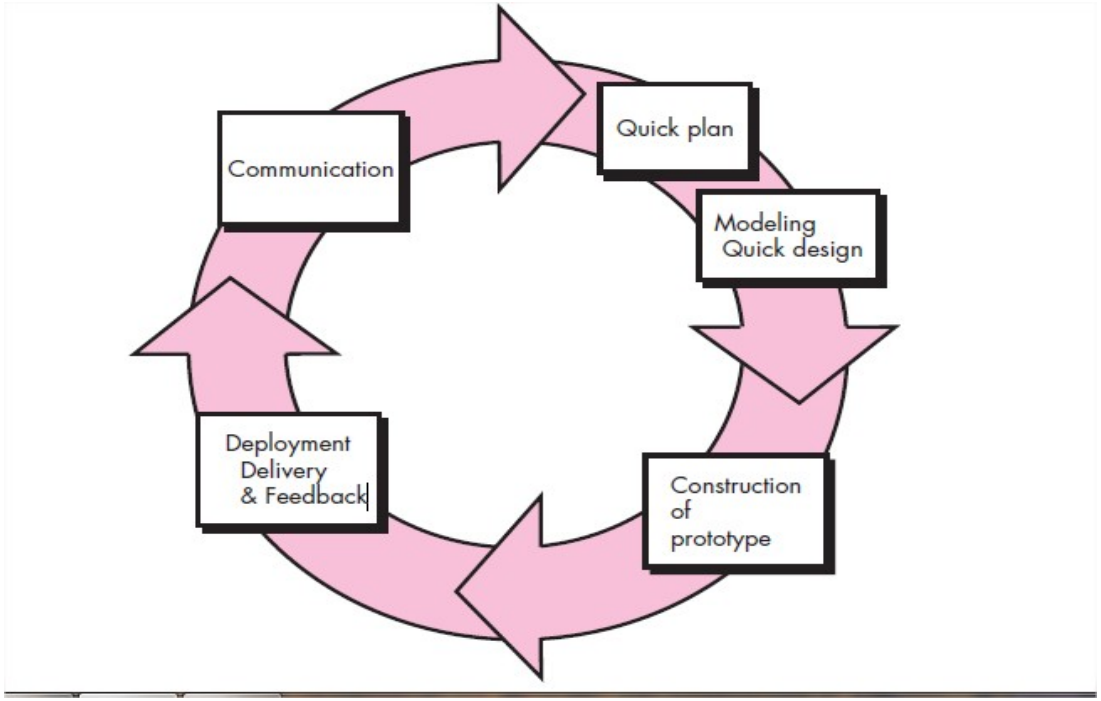


Figure : The prototyping paradigm

Process Model

- **Prototyping**
  - Prototyping serves as a mechanism of identifying software requirements.
  - Prototyping make use of templates.
  - Prototype models can be of following types:
    - **Rapid application development** (Organic mode software - no database, 30 - 90 days).
      Rapid Application Development (RAD) - High speed adaptation of linear sequential model.
    - **Throwaway Prototype**: make use of more than one template.
    - **Evolutionary Prototype**: make use of only one template (prototype slowly evolve into the actual system).

Process Model

- **The Spiral Model**: proposed by Barry Boehm (1988)
  - Couples the iterative nature of prototyping with the controlled and systematic aspects of the waterfall model.
  - Enables the rapid development of more complete version of the software (final product).
  - Risk-driven process model.
  - Unlike other process models that end when software is delivered, the spiral model can be adopted to apply throughout the life cycle of the computer software.

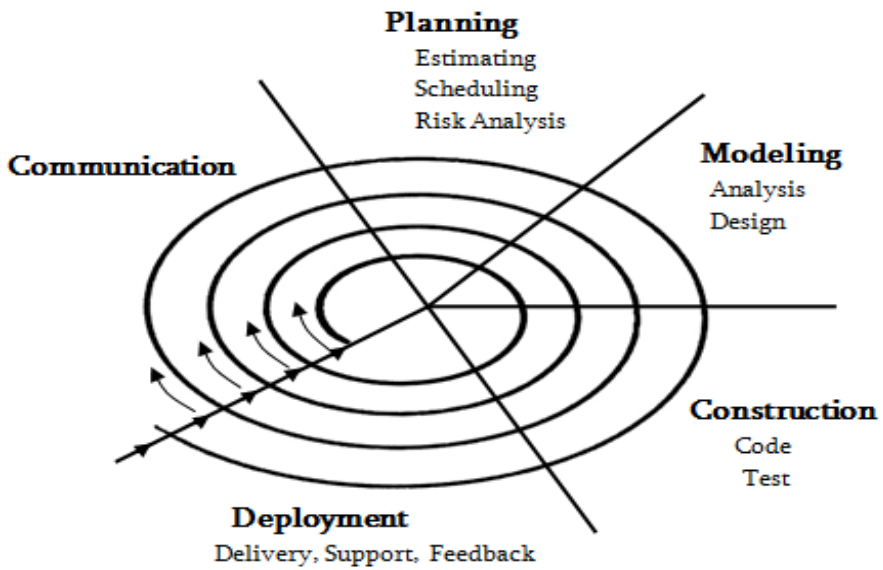


Figure : The typical spiral model

Process Model

- **Concurrent Process Model**
  - It allows a software team to represent iterative and concurrent elements of any of the process model.
  - For example, the modeling activity defined for the spiral model is accomplished by invoking one or more of the software engineering actions: prototyping, analysis, and design.

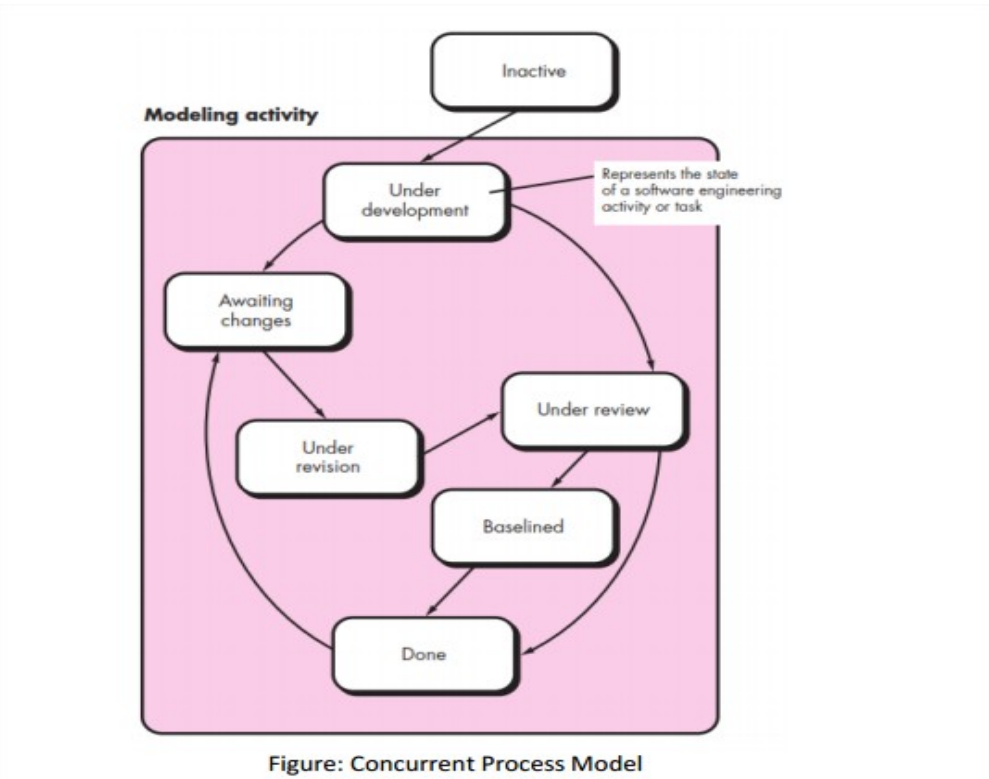


Figure: Concurrent Process Model

Figure : One element of the concurrent process model

Process Model

- **Concurrent Process Model**
  - The activity - modeling, may be in any one of the states noted at any given time.
  - Similarly, other activities, actions, or tasks (e.g., communication or construction) can be represented in an similar manner.
  - All software engineering activities exist concurrently but reside in different states.
  - The modeling activity which existed in the inactive state while initial communication was completed, now makes a transition into the under development state. If, however, the customer indicates that changes in requirements must be made, the modeling activity moves from the under development state into the awaiting changes state.
  - Concurrent modeling defines a series of events that will trigger transitions from state to state for each of the software engineering activities, actions, or tasks.
  - Ideal for small projects with minimal duration.

Process Model

- **Component-based Development Model**
  - Focus is on re-usability of software components or object-oriented classes or packages.
  - Constructs applications from prepackaged software components for e.g. commercial-off-the-shelf (COTS) software components.
  - **Advantage**
    - Reduction in development cycle time and
    - Reduction in project cost.

Process Model

- **Component-based Development Model**

  Steps involved in Component-based Development Model:
  - Available component-based products are researched and evaluated for the application domain in question.
  - Component integration issues are considered.
  - A software architecture is designed to accommodate the components.
  - Components are integrated into the architecture.
  - Comprehensive testing is conducted to ensure proper functionality.

Process Model

- **The Formal Methods Model**
  - Use set of activities that lead to formal mathematical specification of computer software.
  - Enable programmer to specify, develop, and verify a computer-based system by applying a rigorous, mathematical notations.
  - If used properly, formal methods provides a mechanism for eliminating problems (e.g., ambiguity, incompleteness, inconsistency) that are difficult to overcome using other software engineering paradigms.
  - Promise defect-free product.
  - The development of formal models is quite time consuming and expensive.
  - Mostly used for building safety-critical softwares and scientific softwares.

Process Model

- **The Unified Process Model**
  - A framework for object-oriented software engineering using unified modeling language (UML).
  - UML provides robust notation for the modeling and development of object-oriented systems.

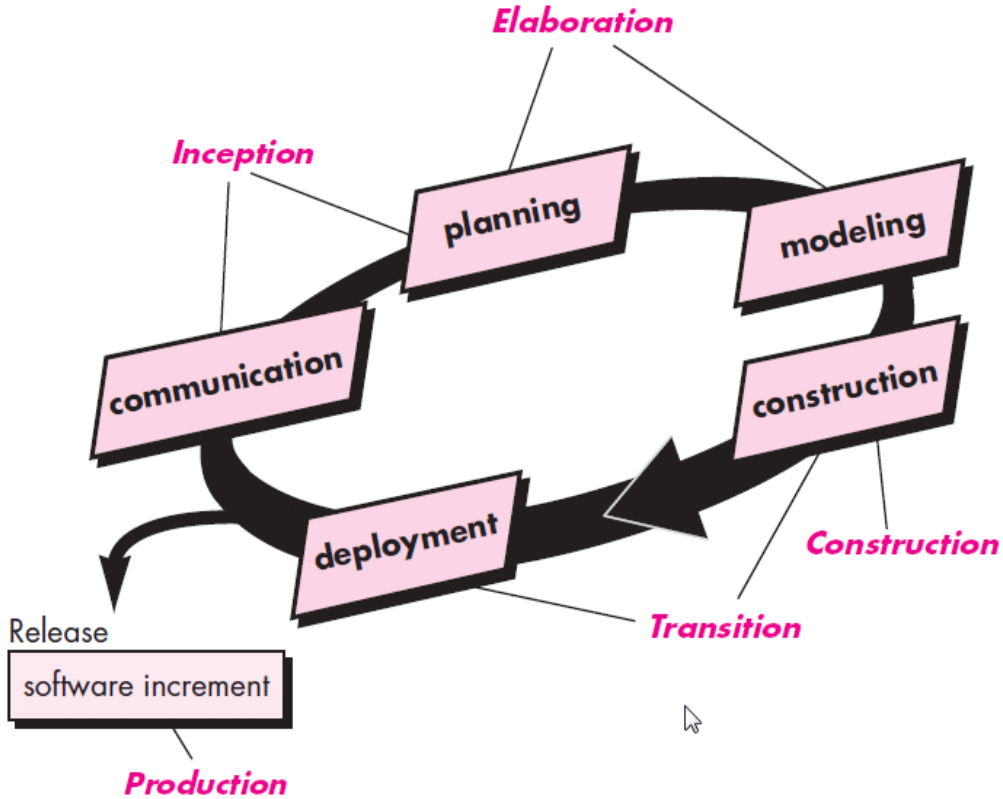


Figure : The unified process

Process Model

Phases of the Unified Process Model

- **Inception Phase**
  - Encompasses both customer communication and planning activities.
  - With the help of stakeholders, business requirements for the software are identified; a rough architecture for the system is proposed; and a plan for the iterative, incremental nature of the ensuing project is developed.
  - Planning identifies resources, assesses major risks, defines a schedule, and establishes a basis for the phases that are to be applied as the software increment is developed.
- **Elaboration Phase**
  - Encompasses the planning and modeling activities of the generic process model.
  - Elaboration refines and expands the preliminary use cases and the architectural representation to include five different views of the software - the use case model, the requirement model, the design model, the implementation model, and the deployment model.

Process Model

Phases of the Unified Process Model

- **Construction Phase**
  - Using the architectural model as input, the construction phase develops or acquires the software components that will make each use case operational for end users.
  - Unit test are designed and executed for each software component.
  - Integration activities (component assembly and integration testing) are conducted.
- **Transition Phase**
  - Software is given to end users for beta testing and user feedback reports both defects and necessary changes.
  - Software team creates the necessary support documents (e.g., user manuals, troubleshooting guides, installation procedures) that is required for the usable software release.

Process Model

Phases of the Unified Process Model

- **Production Phase**: coincides with the deployment phase of the generic process.
  - The ongoing use of the software is monitored, support for the operating environment (infrastructure) is provided, and defect reports and request for changes are submitted and evaluated.

Process Model

- **Personal and Team Process Model**
  - **Key ingredients**: measurement, planning, and self-direction.
  - **Personal Software Process (PSP)**
    - Focus on personal measurement of both the work product that is produced and the resultant quality of the work product.
    - Practitioner is responsible for project planning (e.g., estimating and scheduling).
    - Empowers the practitioner to control the quality of all software work products that are developed.
    - **PSP model activities**: planning, high-level design, high-level design review, development, and postmortem.

Process Model

- **Personal and Team Process Model**
  - **Team Software Process (TSP)**
    - **Goal**: building a "self-directed" project team that organizes itself to produce high-quality software.
    - **PSP model activities**: project launch, high-level design, implementation, integration and test, and postmortem.

Capability Maturity Model (CMM)

- CMM measures the effectiveness of software process.
- Based on the principle of total quality management (TQM).
- **Microsoft** - Synchronized/Stabilized Process Model, **IBM** - Rationalized Unified Process Model (RUP), **Infosys** - Waterfall Model $\Rightarrow$ Spiral Model.

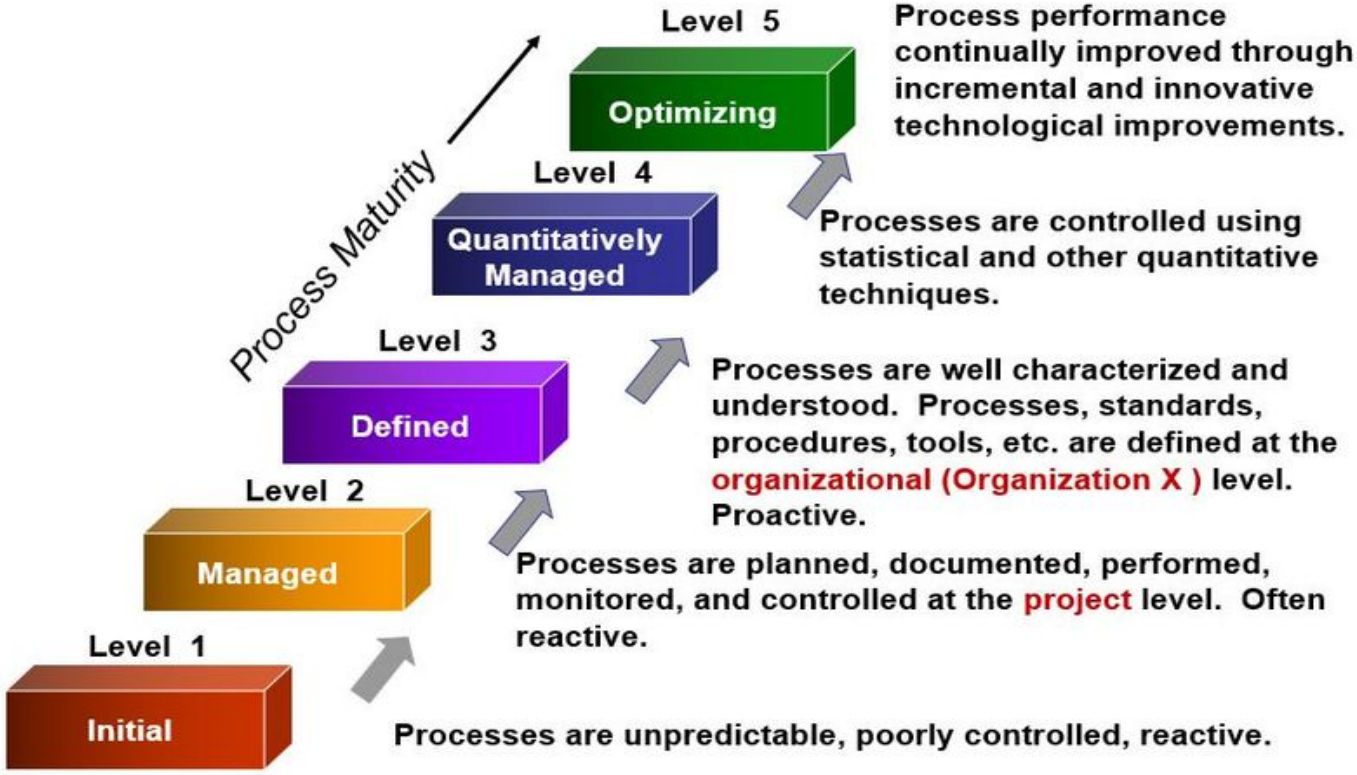


Figure : Capability Maturity Model