“Fundamentals of Product Design”.

- In Section 1 of this course you will cover these topics:
- Journeys In Product Development
- Product Development Process Tools
- Scoping Product Developments: Technical And Business Concerns
- Understanding Customer Needs

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Product Design
- Understand the Product Designers
- Learn about the New Product Development (NPD)

Definition/Overview:

Product design: Product design can be defined as the idea generation, concept development, testing and manufacturing or implementation of a product (physical object or service).

Key Points:

1. Product Designers

Product Designers conceptualize and evaluate ideas, making them tangible through products in a more systematic approach. The role of a product designer encompasses many characteristics of the marketing manager, product manager, industrial designer and design engineer. The term is sometimes equated with industrial design. The role of the product designer combines art, science and technology to create tangible three-dimensional goods. This evolving role has been facilitated by digital tools that allow designers to communicate, visualize and analyze ideas in a way that would have taken greater manpower in the past. Product designers are equipped with the skills needed to bring products from conception to market. They should have the ability to manage design projects, and subcontract areas to other sectors of the design industry. Aesthetics is considered important in Product Design but designers also deal with important aspects including technology, ergonomics, usability, human factors and material technology. As with most of the design fields the idea for the design of a product arises from a need and has a use. It follows a certain method and can sometimes be attributed to more complex factors such as association and telesis. Also used to describe a technically competent product designer or industrial designer is the term Industrial Design Engineer. The Cyclone vacuum cleaner inventor James Dyson for example could be considered to be in this category.

2. New Product Development (NPD)

In business and engineering, new product development (NPD) is the term used to describe the complete process of bringing a new product or service to market. There are two parallel paths involved in the NPD process: one involves the idea generation, product design, and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

3. Application

Some companies or individuals have particularly strong feel for developing new products than others. In the modern world these include especially technological companies like iRobot, Google or Nokia. Many product designers are strategic assets to companies that need to maintain a competitive edge in innovation.

4. Product Focus

In a product innovation approach, the company pursues product innovation, then tries to develop a market for the product. Product innovation drives the process and marketing research is conducted primarily to ensure that profitable market segment(s) exist for the innovation. The rationale is that customers may not know what options will be available to them in the future so we should not expect them to tell us what they will buy in the future. However, marketers can aggressively over-pursue product innovation and try to overcapitalize on a niche. When pursuing a product innovation approach, marketers must ensure that they have a varied and multi-tiered approach to product innovation. It is claimed that if Thomas Edison depended on marketing research he would have produced larger candles rather than inventing light bulbs. Many firms, such as research and development focused companies, successfully focus on product innovation (Such as Nintendo who constantly change the way Video games are played). Many purists doubt whether this is really a form of marketing orientation at all, because of the ex post status of consumer research. Some even question whether it is marketing.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the New Product Development Process
- Understand the Types of New Products
- Learn about the Fuzzy Front End

Definition/Overview:

New Product Development: In business and engineering, new product development (NPD) is the term used to describe the complete process of bringing a new product or service to market.

Key Points:

1. New Product Development Process

There are two parallel paths involved in the NPD process: one involves the idea generation, product design, and detail engineering; the other involves market research and marketing analysis. Companies typically see new product development as the first stage in generating and commercializing new products within the overall strategic process of product life cycle management used to maintain or grow their market share.

2. Types of New Products

There are several general categories of new products. Some are new to the market (ex. DVD players into the home movie market), some are new to the company (ex. Game consoles for Sony), and some are completely novel and create totally new markets (ex. the airline industry). When viewed against a different criterion, some new product concepts are merely minor modifications of existing products while some are completely innovative to the company.

- Changes to Augmented Product
- Core product revision
- Line extensions
- New product lines
- Repositionings
- Completely new

These different characterizations are displayed in the following Figure 1.

1. Fuzzy Front End

The Fuzzy Front End is the messy "getting started" period of new product development processes. It is in the front end where the organization formulates a concept of the product to be developed and decides whether or not to invest resources in the further development of an idea. It is the phase between first considerations of an opportunity and when it is judged ready to enter the structured development process. It includes all activities from the search for new opportunities through the formation of a germ of an idea to the development of a precise concept. The Fuzzy Front End ends when an organization approves and begins formal development of the concept. Although the Fuzzy Front End may not be an expensive part of product development, it can consume 50% of development and it is where major commitments are typically made involving time, money, and the products nature, thus setting the course for the entire project and final end product. Consequently, this phase should be considered as an essential part of development rather than something that happens before development, and its cycle time should be included in the total development cycle time.

- Opportunity Identification
- Opportunity Analysis
- Idea Genesis
- Idea Selection
- Concept and Technology Development

The first element is the opportunity identification. In this element, large or incremental business and technological chances are identified in a more or less structured way. Using the guidelines established here, resources will eventually be allocated to new projects, which then lead to a structured NPPD (New Product & Process Development) strategy. The second element is the opportunity analysis. It is done to translate the identified opportunities into implications for the business and technology specific context of the company. Here extensive efforts may be made to align ideas to target customer groups and do market studies and/or technical trials and research. The third element is the idea genesis, which is described as evolutionary and iterative process progressing from birth to maturation of the opportunity into a tangible idea. The process of the idea genesis can be made internally or come from outside inputs, e.g. a supplier offering a new material/technology, or from a customer with an unusual request. The fourth element is the idea selection. Its purpose is to choose whether to pursue an idea by analyzing its potential business value. The fifth element is the concept and technology development. During this part of the front-end, the business case is developed based on estimates of the total available market, customer needs, investment requirements, competition analysis and project uncertainty. Some organizations consider this to be the first stage of the NPPD process (i.e., Stage 0).

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Product (Business)
- Understand the Process

Definition/Overview:

Product design: Product design can be defined as the idea generation, concept development, testing and manufacturing or implementation of a product (physical object or service).

New Product Development: In business and engineering, new product development (NPD) is the term used to describe the complete process of bringing a new product or service to market.

Key Points:

1. Product (Business)

In marketing, a product is anything that can be offered to a market that might satisfy a want or need. In retailing, products are called merchandise. In manufacturing, products are purchased as raw materials and sold as finished goods. Commodities are usually raw materials such as metals and agricultural products, but a commodity can also be anything widely available in the open market. The verb produce (prə doos’ or -dyoos’) is from the Latin prōdūce(re), (to) lead or bring forth. The noun product (prod'əkt or-ukt) is "a thing produced by labor or effort". Since 1575, the word "product" has referred to anything produced. Since 1695, the word has referred to "thing or things produced". The economic or commercial meaning of product was first used by political economist Adam Smith. In general usage, product may refer to a single item or unit, a group of equivalent products, a grouping of goods or services, or an industrial classification for the goods or services.

2. The Process

2.1. Idea Generation is often called the "fuzzy front end" of the NPD process

Ideas for new products can be obtained from basic research using a SWOT analysis (Opportunity Analysis), Market and consumer trends, company's R&D department, competitors, focus groups, employees, salespeople, corporate spies, trade shows, or Ethnographic discovery methods (searching for user patterns and habits) may also be used to get an insight into new product lines or product features.

Idea Generation or Brainstorming of new product, service, or store concepts idea generation techniques can begin when you have done your Opportunity Analysis to support your ideas in the Idea Screening Phase (shown in the next development step).

2.2. Idea Screening

The object is to eliminate unsound concepts prior to devoting resources to them.

The screeners must ask at least three questions:

- Will the customer in the target market benefit from the product?
- What is the size and growth forecasts of the market segment/target market?
- What is the current or expected competitive pressure for the product idea?
- What are the industry sales and market trends the product idea is based on?
- Is it technically feasible to manufacture the product?
- Will the product be profitable when manufactured and delivered to the customer at the target price?

2.3. Concept Development and Testing

Develop the marketing and engineering details

- Who is the target market and who is the decision maker in the purchasing process?
- What product features must the product incorporate?
- What benefits will the product provide?
- How will consumers react to the product?
- How will the product be produced most cost effectively?
- Prove feasibility through virtual computer aided rendering, and rapid prototyping
- What will it cost to produce it?

Test the concept by asking a sample of prospective customers what they think of the idea.

2.4. Business Analysis

Estimate likely selling price based upon competition and customer feedback

Estimate sales volume based upon size of market and such tools as the Fourt-Woodlock equation

Estimate profitability and breakeven point

2.5. Beta Testing and Market Testing

Produce a physical prototype or mock-up

Test the product (and its packaging) in typical usage situations

Conduct focus group customer interviews or introduce at trade show

Make adjustments where necessary

Produce an initial run of the product and sell it in a test market area to determine customer acceptance

2.6. Technical Implementation

New program initiation

Resource estimation

Requirement publication

Engineering operations planning

Department scheduling

Supplier collaboration

Logistics plan

Resource plan publication

Program review and monitoring

Contingencies - what-if planning

2.7. Commercialization (often considered post-NPD)

Launch the product

Produce and place advertisements and other promotions

Fill the distribution pipeline with product

Critical path analysis is most useful at this stage

These steps may be iterated as needed. Some steps may be eliminated. To reduce the time that the NPD process takes, many companies are completing several steps at the same time (referred to as concurrent engineering or time to market). Most industry leaders see new product development as a proactive process where resources are allocated to identify market changes and seize upon new product opportunities before they occur (in contrast to a reactive strategy in which nothing is done until problems occur or the competitor introduces an innovation). Many industry leaders see new product development as an ongoing process (referred to as continuous development) in which the entire organization is always looking for opportunities. For the more innovative products indicated on the diagram above, great amounts of uncertainty and change may exist, which makes it difficult or impossible to plan the complete project before starting it. In this case, a more flexible approach may be advisable. Because the NPD process typically requires both engineering and marketing expertise, cross-functional teams are a common way of organizing projects. The team is responsible for all aspects of the project, from initial idea generation to final commercialization, and they usually report to senior management (often to a vice president or Program Manager). In those industries where products are technically complex, development research is typically expensive, and product life cycles are relatively short, strategic alliances among several organizations helps to spread the costs, provide access to a wider skill set, and speeds the overall process.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Customer Needs
- Understand the How To Be A Good Customer
- Learn about the Customer Relationship Management

Definition/Overview:

Customer: A customer refers to individuals or households that purchase goods and services generated within the economy. The word historically derives from "custom," meaning "habit"; a customer was someone who frequented a particular shop, who made it a habit to purchase goods there, and with whom the shopkeeper had to maintain a relationship to keep his or her "custom," meaning expected purchases in the future.

Key Points:

1. Customer Needs

Customer needs may be defined as the goods or services a customer requires to achieve specific goals. Different needs are of varying importance to the customer. Customer expectations are influenced by cultural values, advertising, marketing, and other communications, both with the supplier and with other sources. Both customer needs and expectations may be determined through interviews, surveys, conversations, data mining or other methods of collecting information. Customers at times do not have a clear understanding of their needs. Assisting in determining needs can be a valuable service to the customer. In the process, expectations may be set or adjusted to correspond to known product capabilities or service.

2. How to be a Good Customer

- Allow your agency to work on your account, free from fear
- Select the right agency in the first place
- Brief your agency thoroughly
- Make sure your agency makes a profit
- Set high standards
- Test everything
- Don't waste time
- Be tolerant
- Don't under-spend

3. Customer Relationship Management

Customer relationship management (CRM) consists of the processes a company uses to track and organize its contacts with its current and prospective customers. CRM software is used to support these processes; information about customers and customer interactions can be entered, stored and accessed by employees in different company departments. Typical CRM goals are to improve services provided to customers, and to use customer contact information for targeted marketing. While the term CRM generally refers to a software-based approach to handling customer relationships, most CRM software vendors stress that a successful CRM effort requires a holistic approach. CRM initiatives often fail because implementation was limited to software installation, without providing the context, support and understanding for employees to learn, and take full advantage of the information systems.

4. Customer Experience

Customer experience is the sum of all experiences a customer has with a supplier of goods or services, over the duration of their relationship with that supplier. It can also be used to mean an individual experience over one transaction; the distinction is usually clear in context. Customer experience is the new innovation frontier for business. Companies are focusing on the importance of the experience and, as Jeananne Rae notes, realizing that building great consumer experiences is a complex enterprise, involving strategy, integration of technology, orchestrating business models, brand management and CEO commitment. An Enterprise Feedback Management (EFM) system can be used to collect value feedback from customers. Microsofts Customer Experience Improvement Program gives all of its customers the opportunity to provide input into the design and development of its products. The program collects feedback on how customers use Microsoft programs and problems they have encountered. The end results are software improvements to better meet customer needs. Customer-centric service providers take care of customer needs at every touch-point in the customer lifecycle (ordering, fulfillment, billing, support, etc.) and employ all channels (contact center, Internet, self service, mobile devices, brick and mortar stores) and means of communication (phone, chat, email, Web, in-person). They develop experience-based differentiation, which shifts the focus from product features to customer wants and needs. These experience-based providers integrate both internal and external innovations to create end-to-end customer experiences. They evaluate their business models as well as business support systems and operational support systems (BSS/OSS) from the customers point of view to achieve the level of customer-centricity necessary to improve customer loyalty, churn and revenue.

In Section 2 of this course you will cover these topics:

- Establishing Product Function
- Product Teardown And Experimentation
- Benchmarking And Establishing Engineering Specifications
- Product Portfolios And Portfolio Architecture

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Production Function
- Understand the Stages of Production

Definition/Overview:

Production function: A production function is microeconomics function that specifies the output in an industry for all combinations of inputs.

Product: In marketing, a product is anything that can be offered to a market that might satisfy a want or need.

Key Points:

1. Production function

A production function is microeconomics function that specifies the output in an industry for all combinations of inputs. A meta-production function (sometimes metaproduction function) compares the practice of the existing entities converting inputs X into output y to determine the most efficient practice production function of the existing entities, whether the most efficient feasible practice production or the most efficient actual practice production. In either case, the maximum output of a technologically-determined production process is a mathematical function of input factors of production. Put another way, given the set of all technically feasible combinations of output and inputs, only the combinations encompassing a maximum output for a specified set of inputs would constitute the production function. Alternatively, a production function can be defined as the specification of the minimum input requirements needed to produce designated quantities of output, given available technology. It is usually presumed that unique production functions can be constructed for every production technology. By assuming that the maximum output technologically possible from a given set of inputs is achieved, economists using a production function in analysis are abstracting away from the engineering and managerial problems inherently associated with a particular production process. The engineering and managerial problems of technical efficiency are assumed to be solved, so that analysis can focus on the problems of allocative efficiency. The firm is assumed to be making allocative choices concerning how much of each input factor to use, given the price of the factor and the technological determinants represented by the production function. A decision frame, in which one or more inputs are held constant, may be used; for example, capital may be assumed to be fixed or constant in the short run, and only labor variable, while in the long run, both capital and labor factors are variable, but the production function itself remains fixed, while in the very long run, the firm may face even a choice of technologies, represented by various, possible production functions.

The relationship of output to inputs is non-monetary, that is, a production function relates physical inputs to physical outputs, and prices and costs are not considered. But, the production function is not a full model of the production process: it deliberately abstracts away from essential and inherent aspects of physical production processes, including error, entropy or waste. Moreover, production functions do not ordinarily model the business processes, either, ignoring the role of management, of sunk cost investments and the relation of fixed overhead to variable costs. (For a primer on the fundamental elements of microeconomic production theory, see production theory basics). The primary purpose of the production function is to address allocative efficiency in the use of factor inputs in production and the resulting distribution of income to those factors. Under certain assumptions, the production function can be used to derive a marginal product for each factor, which implies an ideal division of the income generated from output into an income due to each input factor of production.

2. The Production Function as an Equation

There are several ways of specifying the production function. In a general mathematical form, a production function can be expressed as:

$$Q = f(X_1,X_2,X_3,...,X_n)$$

where:

Q = quantity of output

$X_1, X_2, X_3, ..., X_n$ = factor inputs (such as capital, labor, land or raw materials). This general form does not encompass joint production that is a production process, which has multiple co-products or outputs.

One way of specifying a production function is simply as a table of discrete outputs and input combinations, and not as a formula or equation at all. Using an equation usually implies continual variation of output with minute variation in inputs, which is simply not realistic. Fixed ratios of factors, as in the case of laborers and their tools, might imply that only discrete input combinations, and therefore, discrete maximum outputs, are of practical interest.
One formulation is as a linear function:

$$Q = a + bX_1 + cX_2 + dX_3, ...$$

Where a, b, c, and d are parameters that are determined empirically.

Another is as a Cobb-Douglas production function (multiplicative):

Other forms include the constant elasticity of substitution production function (CES) which is a generalized form of the Cobb-Douglas function, and the quadratic production function which is a specific type of additive function. The best form of the equation to use and the values of the parameters (a, b, c, and d) vary from company to company and industry to industry. In a short run production function at least one of the X's (inputs) is fixed. In the long run all factor inputs are variable at the discretion of management.

3. The Production Function as a Graph

Any of these equations can be plotted on a graph. A typical (quadratic) production function is shown in the following diagram. All points above the production function are unobtainable with current technology, all points below are technically feasible, and all points on the function show the maximum quantity of output obtainable at the specified levels of inputs. From the origin, through points A, B, and C, the production function is rising, indicating that as additional units of inputs are used, the quantity of outputs also increases. Beyond point C, the employment of additional units of inputs produces no additional outputs, in fact, total output starts to decline. The variable inputs are being used too intensively (or to put it another way, the fixed inputs are under utilized). With too much variable input use relative to the available fixed inputs, the company is experiencing negative returns to variable inputs, and diminishing total returns. In the diagram this is illustrated by the negative marginal physical product curve (MPP) beyond point Z, and the declining production function beyond point C.

From the origin to point A, the firm is experiencing increasing returns to variable inputs. As additional inputs are employed, output increases at an increasing rate. Both marginal physical product (MPP) and average physical product (APP) is rising. The inflection point A, defines the point of diminishing marginal returns, as can be seen from the declining MPP curve beyond point X. From point A to point C, the firm is experiencing positive but decreasing returns to variable inputs. As additional inputs are employed, output increases but at a decreasing rate. Point B is the point of diminishing average returns, as shown by the declining slope of the average physical product curve (APP) beyond point Y. Point B is just tangent to the steepest ray from the origin hence the average physical product is at a maximum. Beyond point B, mathematical necessity requires that the marginal curve must be below the average curve.

4. The Stages of Production

To simplify the interpretation of a production function, it is common to divide its range into 3 stages. In Stage 1 (from the origin to point B) the variable input is being used with increasing efficiency, reaching a maximum at point B (since the average physical product is at its maximum at that point). The average physical product of fixed inputs will also be rising in this stage (not shown in the diagram). Because the efficiency of both fixed and variable inputs is improving throughout stage 1, a firm will always try to operate beyond this stage. In stage 1, fixed inputs are underutilized. In Stage 2, output increases at a decreasing rate, and the average and marginal physical product is declining. However the average product of fixed inputs (not shown) is still rising. In this stage, the employment of additional variable inputs increase the efficiency of fixed inputs but decrease the efficiency of variable inputs. The optimum input/output combination will be in stage 2. Maximum production efficiency must fall somewhere in this stage. Note that this does not define the profit maximizing point. It takes no account of prices or demand. If demand for a product is low, the profit maximizing output could be in stage 1 even though the point of optimum efficiency is in stage 2. In Stage 3, too much variable input is being used relative to the available fixed inputs: variable inputs are over utilized. Both the efficiency of variable inputs and the efficiency of fixed inputs decline through out this stage. At the boundary between stage 2 and stage 3, fixed input is being utilized most efficiently and short-run output is maximum.

5. Shifting a Production Function

As noted above, it is possible for the profit maximizing output level to occur in any of the three stages. If profit maximization occurs in either stage 1 or stage 3, the firm will be operating at a technically inefficient point on its production function. In the short run it can try to alter demand by changing the price of the output or adjusting the level of promotional expenditure. In the long run the firm has more options available to it, most notably, adjusting its production processes so they better match the characteristics of demand. This usually involves changing the scale of operations by adjusting the level of fixed inputs. If fixed inputs are lumpy, adjustments to the scale of operations may be more significant than what is required to merely balance production capacity with demand. For example, you may only need to increase production by a million units per year to keep up with demand, but the production equipment upgrades that are available may involve increasing production by 2 million units per year.

If a firm is operating (inefficiently) at a profit maximizing level in stage one, it might, in the long run, choose to reduce its scale of operations (by selling capital equipment). By reducing the amount of fixed capital inputs, the production function will shift down and to the left. The beginning of stage 2 shifts from B1 to B2. The (unchanged) profit maximizing output level will now be in stage 2 and the firm will be operating more efficiently. If a firm is operating (inefficiently) at a profit maximizing level in stage three, it might, in the long run, choose to increase its scale of operations (by investing in new capital equipment). By increasing the amount of fixed capital inputs, the production function will shift up and to the right. For example, if it takes 5 pounds of sugar to make 2 cookies, then the production function would be 5 to 2. It would also be 10 to 4. 4 cookies for every 10 pounds of sugar.

6. Homogeneous and Homothetic Production Functions

There are two special classes of production functions that are frequently mentioned in textbooks but are seldom seen in reality. The production function $Q = f(X_1,X_2)$ is said to be homogeneous of degree n, if given any positive constant k, $f(kX_1,kX_2) = k^n f(X_1,X_2)$. When $n > 1$, the function exhibits increasing returns, and decreasing returns when $n < 1$. When it is homogeneous of degree 1, it exhibits constant returns. Homothetic functions are functions whose marginal technical rate of substitution (slope of the isoquant) is homogeneous of degree zero. Due to this, along rays coming from the origin, the slope of the isoquants will be the same.

7. Aggregate Production Functions

In macroeconomics, production functions for whole nations are sometimes constructed. In theory they are the summation of all the production functions of individual producers, however this is an impractical way of constructing them. There are also methodological problems associated with aggregate production functions.

8. Criticisms of Production Functions

During the 1950s, 60s, and 70s there was a lively debate about the theoretical soundness of production functions. Although most of the criticism was directed primarily at aggregate production functions, microeconomic production functions were also put under scrutiny. The debate began in 1953 when Joan Robinson criticized the way the factor input, capital, was measured and how the notion of factor proportions had distracted economists. According to the argument, it is impossible to conceive of an abstract quantity of capital which is independent of the rates of interest and wages. The problem is that this independence is a precondition of constructing an iso-product curve. Further, the slope of the iso-product curve helps determine relative factor prices, but the curve cannot be constructed (and its slope measured) unless the prices are known beforehand.

Neoclassical economists often omit natural resources from production functions. When Solow and Stiglitz sought to make the production function more realistic by adding in natural resources, they did it in a manner that economist Georgescu-Roegen criticized as a "conjuring trick" that failed to address the laws of thermodynamics and would imply that to make a cake, all that is needed is a cook, a kitchen, and some non-zero amount of ingredients. The model is absurd in that it suggests that the size of the cake could be expanded indefinitely without extra ingredients. Neither Solow nor Stiglitz addressed his criticism, despite an invitation to do so in the September 1997 issue of the journal Ecological Economics. This may seem like a highly technical argument amongst competing schools of economists, but conceding the point would involve admitting that much of growth theory flounders on the rocks of biophysical limits and may help explain why economists have by and large failed to understand and anticipate emerging environmental problems such as climate change.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Product Teardown
- Understand the Experimentation

Definition/Overview:

Product Teardown: A product teardown, or simply teardown, has an increasing interest in the technical community to provide answers as to which semiconductor components are utilized in various consumer electronic products, such as the Wii video game console and Apple's iPhone (as well the myriad of other mobile phones).

Production function: A production function is microeconomics function that specifies the output in an industry for all combinations of inputs.

Key Points:

1. Product Teardown

A product teardown, or simply teardown, has an increasing interest in the technical community to provide answers as to which semiconductor components are utilized in various consumer electronic products, such as the Wii video game console and Apple's iPhone (as well the myriad of other mobile phones). Seeing what is inside of these systems can help the technical community to better understand how everything works, who has design wins, and can provide an estimate on the bill of materials. The financial community has an interest in teardowns, as it can help them guide stock valuation, as often companies are not allowed to announce that they are used in a system due to non-disclosure agreements. Finally, consumers are interested in finding out what makes their products "tick", but do not want to damage them by tearing them down. Identifying semiconductor components in systems has become more difficult over the past years. The most notable change started with Apple's 8GB iPod nano, where they took readily available components, such as the Wolfson Microelectonics WM8750, and repackaged it with Apple branding. This makes it more difficult to identify the actual device manufacturer and function of the component without performing a decap removing the outer packaging to analyze the die within. Typically there are markings on the die inside the package that can lead experienced engineers to who actually created the device and what functionality it performs in the system. Teardowns have also been performed in front of a live studio audience at the Embedded Systems Conference. The first live teardown was performed on a Toyota Prius at the Embedded Systems Conference in San Jose, April 2006. Since that time, additional live teardowns have been performed, most recently being the Sony OLED TV, Gibson Self-Tuning Guitar, SuitSat space suit, and Sony Rolly MP3 player. There seem to be two major companies that perform teardowns - Portelligent and Semiconductor Insights, both of which write featured articles in EETimes and

TechOnline on their findings. Both companies were acquired by TechInsights, a division of United Business Media in 2007. While Semiconductor Insights still remains focused on their other business opportunities, their teardown services, as well as Portelligent, are now part of TechOnline, which is a subgroup of United Business Media's TechInsights division. There also appear to be three main authors from these companies that write the articles. David Carey, President for Portelligent, Jeff Brown, Senior Analyst for Portelligent, and Gregory A. Quirk, Technical Marketing Manager for TechOnline.

2. Experimentation

In scientific inquiry, an experiment (Latin: ex- periri, "to try out") is a method of investigating causal relationships among variables. An experiment is a cornerstone of the empirical approach to acquiring data about the world and is used in both natural sciences and social sciences. An experiment can be used to help solve practical problems and to support or negate theoretical assumptions. Human experimentation requires special safeguards against outside variables such as the placebo effect. Such experiments are generally double blind, meaning that neither the volunteer nor the researcher knows which individuals are in the control group or the experimental group until after all of the data have been collected. This ensures that any effects on the volunteer are due to the treatment itself and are not a response to the knowledge that he is being treated. In human experiments, a subject (person) may be given a stimulus to which he or she should respond. The goal of the experiment is to measure the response to a given stimulus by a test method.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Benchmarking
- Understand the Advantages of Benchmarking
- Learn about the Collaborative Benchmarking

- Understand the Procedure, Cost and Types of Benchmarking

Definition/Overview:

Benchmarking: Benchmarking (also "best practice benchmarking" or "process benchmarking") is a process used in management and particularly strategic management, in which organizations evaluate various aspects of their processes in relation to best practice, usually within their own sector.

Key Points:

1. Advantages of Benchmarking

Benchmarking (also "best practice benchmarking" or "process benchmarking") is a process used in management and particularly strategic management, in which organizations evaluate various aspects of their processes in relation to best practice, usually within their own sector. This then allows organizations to develop plans on how to adopt such best practice, usually with the aim of increasing some aspect of performance. Benchmarking may be a one-off event, but is often treated as a continuous process in which organizations continually seek to challenge their practices. Benchmarking in simplistic terms is the process where you compare your process with that of a better process and try to improve the standard of the process you follow to improve quality of the system, product, services etc. A process similar to benchmarking is also used in technical product testing and in land surveying. See the article benchmark for these applications. Benchmarking is a powerful management tool because it overcomes "paradigm blindness." Paradigm Blindness can be summed up as the mode of thinking, "The way we do it is the best because this is the way we've always done it." Benchmarking opens organizations to new methods, ideas and tools to improve their effectiveness. It helps crack through resistance to change by demonstrating other methods of solving problems than the one currently employed, and demonstrating that they work, because they are being used by others.

2. Collaborative Benchmarking

Benchmarking, originally invented as a formal process by Rank Xerox, is usually carried out by individual companies. Sometimes it may be carried out collaboratively by groups of companies (e.g. subsidiaries of a multinational in different countries). One example is that of the Dutch municipally-owned water supply companies, which have carried out a voluntary collaborative benchmarking process since 1997 through their industry association.

3. Procedure

There is no single benchmarking process that has been universally adopted. The wide appeal and acceptance of benchmarking has led to various benchmarking methodologies emerging. The most prominent methodology is the 12 stage methodology by Robert Camp. The 12 stage methodology consisted of 1. Select subject ahead 2. Define the process 3. Identify potential partners 4. Identify data sources 5. Collect data and select partners 6. Determine the gap 7. Establish process differences 8. Target future performance 9. Communicate 10. Adjust goal 11. Implement 12. Review/recalibrate.

The following is an example of a typical shorter version of the methodology:

- Identify your problem areas - Because benchmarking can be applied to any business process or function, a range of research techniques may be required. They include: informal conversations with customers, employees, or suppliers; exploratory research techniques such as focus groups; or in-depth marketing research, quantitative research, surveys, questionnaires, re engineering analysis, process mapping, quality control variance reports, or financial ratio analysis. Before embarking on comparison with other organizations it essential that you know your own organization's function, process; base lining performance provides a point against which improvement effort can be measured.

- Identify other industries that have similar processes - For instance if one were interested in improving hand offs in addiction treatment s/he would try to identify other fields that also have hand off challenges. These could include air traffic control, cell phone switching between towers, transfer of patients from surgery to recovery rooms.
- Identify organizations that are leaders in these areas - Look for the very best in any industry and in any country. Consult customers, suppliers, financial analysts, trade associations, and magazines to determine which companies are worthy of study.
- Survey companies for measures and practices - Companies target specific business processes using detailed surveys of measures and practices used to identify business process alternatives and leading companies. Surveys are typically masked to protect confidential data by neutral associations and consultants.
- Visit the "best practice" companies to identify leading edge practices - Companies typically agree to mutually exchange information beneficial to all parties in a benchmarking group and share the results within the group.
- Implement new and improved business practices - Take the leading edge practices and develop implementation plans which include identification of specific opportunities, funding the project and selling the ideas to the organization for the purpose of gaining demonstrated value from the process.

4. Cost of Benchmarking

Benchmarking is a moderately expensive process, but most organizations find that it more than pays for itself. The three main types of costs are:

- Visit Costs - This includes hotel rooms, travel costs, meals, a token gift, and lost labor time.
- Time Costs - Members of the benchmarking team will be investing time in researching problems, finding exceptional companies to study, visits, and implementation. This will

take them away from their regular tasks for part of each day so additional staff might be required.

- Benchmarking Database Costs - Organizations that institutionalize benchmarking into their daily procedures find it is useful to create and maintain a database of best practices and the companies associated with each best practice now.

The cost of benchmarking can substantially be reduced through utilizing the many internet resources that have sprung up over the last few years. These aim to capture benchmarks and best practices from organizations, business sectors and countries to make the benchmarking process much quicker and cheaper.

5. Technical benchmarking or Product Benchmarking

The technique initially used to compare existing corporate strategies with a view to achieving the best possible performance in new situations, has recently been extended to the comparison of technical products. This process is usually referred to as "Technical Benchmarking" or "Product Benchmarking'. Its use is particularly well developed within the automotive industry ("Automotive Benchmarking"), where it is vital to design products that match precise user expectations, at minimum possible cost, by applying the best technologies available worldwide. Many data are obtained by fully disassembling existing cars and their systems. Such analyses were initially carried out in-house by car makers and their suppliers. However, as they are expensive, they are increasingly outsourced to companies specialized in this area. Indeed, outsourcing has enabled a drastic decrease in costs for each company (by cost sharing) and the development of very efficient tools (standards, software).

6. Types of Benchmarking

- Process benchmarking - the initiating firm focuses its observation and investigation of business processes with a goal of identifying and observing the best practices from one or more benchmark firms. Activity analysis will be required where the objective is to benchmark cost and efficiency; increasingly applied to back-office processes where outsourcing may be a consideration.

- Financial benchmarking - performing a financial analysis and comparing the results in an effort to assess your overall competitiveness.
- Performance benchmarking - allows the initiator firm to assess their competitive position by comparing products and services with those of target firms.
- Product benchmarking - the process of designing new products or upgrades to current ones. This process can sometimes involve reverse engineering which is taking apart competitors products to find strengths and weaknesses.
- Strategic benchmarking - involves observing how others compete. This type is usually not industry specific meaning it is best to look at other industries.
- Functional benchmarking - a company will focus its benchmarking on a single function in order to improve the operation of that particular function. Complex functions such as Human Resources, Finance and Accounting and Information and Communication Technology are unlikely to be directly comparable in cost and efficiency terms and may need to be disaggregated into processes to make valid comparison.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Portfolio
- Understand the Project Portfolio Management
- Learn about the Implementation of Project Portfolio Management

Definition/Overview:

Portfolio: In finance, a portfolio is an appropriate mix of or collection of investments held by an institution or a private individual.

Key Points:

1. Project Portfolio Management

Project Portfolio Management (PPM) is a term used by project managers and project management (PM) organizations to describe methods for analyzing and collectively managing a group of current or proposed projects based on numerous key characteristics. The fundamental objective of the PPM process is to determine the optimal mix and sequencing of proposed projects to best achieve the organization's overall goals - typically expressed in terms of hard economic measures, business strategy goals, or technical strategy goals - while honoring constraints imposed by management or external real-world factors. Typical attributes of projects being analyzed in a PPM process include each project's total expected cost, consumption of scarce resources (human or otherwise) expected timeline and schedule of investment, expected nature, magnitude and timing of benefits to be realized, and relationship or inter-dependencies with other projects in the portfolio.

2. Implementation of Project Portfolio Management

The key challenge to implementing an effective PPM process is typically securing the mandate to do so. Many organizations are culturally inured to an informal method of making project investment decisions, which can be compared to political processes observable in the U.S. legislature. However this approach to making project investment decisions has led many organizations to unsatisfactory results, and created demand for a more methodical and transparent decision making process. That demand has in turn created a commercial marketplace for tools and systems which facilitate such a process. Some commercial vendors of PPM software emphasize their products' ability to treat projects as part of an overall investment portfolio. PPM advocates see it as a shift away from one-off, ad hoc approaches to project investment decision making. Most PPM tools and methods attempt to establish a set of values, techniques and technologies that enable visibility, standardization, measurement and process improvement. PPM tools attempt to enable organizations to manage the continuous flow of projects from concept to completion. Treating a set of projects as a portfolio would be, in most cases, an improvement on the ad hoc, one-off analysis of individual project proposals. The relationship between PPM techniques and existing investment analysis methods is a matter of debate. While many are represented as "rigorous" and "quantitative", few PPM tools attempt to incorporate established financial portfolio optimization methods like modern portfolio theory or Applied Information Economics, which have been applied to project portfolios, including even non-financial issues.

3. Controversy over the "investment discipline" of PPM

Developers of PPM tools see their solutions as borrowing from the financial investment world. However, other than using the word "portfolio", few can point to any specific portfolio optimization methods implemented in their tools. A project can be viewed as a composite of resource investments such as skilled labour and associated salaries, IT hardware and software, and the opportunity cost of deferring other project work. As project resources are constrained, business management can derive greatest value by allocating these resources towards project work that is objectively and relatively determined to meet business objectives more so than other project opportunities. Thus, the decision to invest in a project can be made based upon criteria that measure the relative benefits (e.g. supporting business objectives) and its relative costs and risks to the organization. In principle, PPM attempts to address issues of resource allocation, e.g., money, time, people, capacity, etc. In order for it to truly borrow concepts from the financial investment world, the portfolio of projects and hence the PPM movement should be grounded in some financial objective such as increasing shareholder value, top line growth, etc. Equally important, risks must be computed in a statistically, actuarially meaningful sense. Optimizing resources and projects without these in mind fails to consider the most important resource any

organization has and which is easily understood by people throughout the organization whether they be IT, finance, marketing, etc and that resource is money.
While being tied largely to IT and fairly synonymous with IT portfolio management, PPM is ultimately a subset of corporate portfolio management and should be exportable/utilized by any group selecting and managing discretionary projects. However, most PPM methods and tools opt for various subjective weighted scoring methods, not quantitatively rigorous methods based on options theory, modern portfolio theory, Applied Information Economics or operations research.

Beyond the project investment decision, PPM aims to support ongoing measurement of the project portfolio so each project can be monitored for its relative contribution to business goals. If a project is either performing below expectations (cost overruns, benefit erosion) or is no longer highly aligned to business objectives (which change with natural market and statutory evolution), management can choose to decommit from a project and redirect its resources elsewhere. This analysis, done periodically, will "refresh" the portfolio to better align with current states and needs. Historically, many organizations were criticized for focusing on "doing the wrong things well." PPM attempts to focus on a fundamental question: "Should we be doing this project or this portfolio of projects at all?" One litmus test for PPM success is to ask "Have you ever canceled a project that was on time and on budget?" With a true PPM approach in place, it is much more likely that the answer is "yes." As goals change so should the portfolio mix of what projects are funded or not funded no matter where they are in their individual lifecycles. Making these portfolio level business investment decisions allows the organization to free up resources, even those on what were before considered "successful" projects, to then work on what is really important to the organization.

4. Optimizing for payoff

One method PPM tools or consultants might use is the use of decision trees with decision nodes that allow for multiple options and optimize against a constraint. The organization in the following example has options for 7 projects but the portfolio budget is limited to $10,000,000. The selection made are the projects 1, 3, 6 and 7 with a total investment of $7,740,000 - the optimum under these conditions. The portfolio's payoff is $2,710,000.

Presumably, all other combinations of projects would either exceed the budget or yield a lower payoff. However, this is an extremely simplified representation of risk and is unlikely to be realistic. Risk is usually a major differentiator among projects but it is difficult to quantify risk in a statistically and actuarially meaningful manner (with probability theory, Monte Carlo Method, statistical analysis, etc.). This places limits on the deterministic nature of the results of a tool such as a decision tree (as predicted by modern portfolio theory.

5. Resource Allocation

Resource allocation is a critical component of PPM. Once it is determined that one or many projects meet defined objectives, the available resources of an organization must be evaluated for its ability to meet this project demand (aka as a demand "pipeline" discussed below). Effective resource allocation typically requires an understanding of existing labor or funding resource commitments (in either business operations or other projects) as well as the skills available in the resource pool. Project investment should only be made in projects where the necessary resources are available during a specified period of time. Resources may be subject to physical constraints. For example, IT hardware may not be readily available to support technology changes associated with ideal implementation timeframe for a project. Thus, a holistic understanding of all project resources and their availability must be conjoined with the decision to make initial investment or else projects may encounter substantial risk during their lifecycle when unplanned resource constraints arise to delay achieving project objectives. Beyond the project investment decision, PPM involves ongoing analysis of the project portfolio so each investment can be monitored for its relative contribution to business goals versus other portfolio investments. If a project is either performing below expectations (cost overruns, benefit erosion) or is no longer aligned to business objectives (which change with natural market and statutory evolution), management can choose to decommit from a project to stem further investment and redirect resources towards other projects that better fit business objectives. This analysis can typically be performed on a periodic basis (eg. quarterly or semi-annually) to "refresh" the portfolio for optimal business performance. In this way both new and existing projects are continually monitored for their contributions to overall portfolio health. If PPM is applied in this manner, management can more clearly and transparently demonstrate its effectiveness to its shareholders or owners.

Implementing PPM at the enterprise level faces a challenge in gaining enterprise support because investment decision criteria and weights must be agreed to by the key stakeholders of the organization, each of whom may be incentivized to meet specific goals that may not necessarily align with those of the entire organization. But if enterprise business objectives can be manifested in and aligned with the objectives of its distinct business unit sub-organizations, portfolio criteria agreement can be achieved more easily. From a requirements management perspective Project Portfolio Management can be viewed as the upper-most level of business requirements management in the company, seeking to understand the business requirements of the company and what portfolio of projects should be undertaken to achieve them. It is through portfolio management that each individual project should receive its allotted business requirements.

6. Pipeline Management

In addition to managing the mix of projects in a company, Project Portfolio Management must also determine whether (and how) a set of projects in the portfolio can be executed by a company in a specified time, given finite development resources in the company. This is called pipeline management. Fundamental to pipeline management is the ability to measure the planned allocation of development resources according to some strategic plan. To do this, a company must be able to estimate the effort planned for each project in the portfolio, and then roll the results up by one or more strategic project types e.g., effort planned for research projects. Discusses project portfolio and pipeline management in the context of use case driven development.

7. Organizational Applicability

The complexity of PPM and other approaches to IT projects (e.g., treating them as a capital investment) may render them not suitable for smaller or younger organizations. An obvious reason for this is that a few IT projects doesn't make for much of a portfolio selection. Other reasons include the cost of doing PPM the data collection, the analysis, the documentation, the education, and the change to decision-making processes.

In Section 3 of this course you will cover these topics:

- Product Architecture
- Generating Concepts
- Concept Selection
- Concept Embodiment

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Technical architecture
- Understand the Steps, Process and Requirements

Definition/Overview:

Technical architecture: Technical architecture (TA) refers to the structured process of designing and building a systems architecture, with focus on the users' and sponsors' view of the environment. Where a TA is used, the systems architecture then focuses on the engineering view of the environment.

Key Points:

1. Technical architecture

Technical architecture is a part of software architecture, which focuses on how to deal with certain aspects of the software engineering process. It allows us to design better systems by:

- Meeting system requirements and objectives: Both functional and non-functional requirements can be prioritized as "must have", "should have" or "want", where "must have" identifies properties that the system must have in order to be acceptable. An architecture allows us to evaluate and make tradeoffs among requirements of differing priority. Though system qualities (also known as non-functional requirements) can be compromised later in the development process, many will not be met if not explicitly taken into account at the architectural level.
- Enabling flexible partitioning of the system: A good architecture enables flexible distribution of the system by allowing the system and its constituent applications to be partitioned among processors in many different ways without having to redesign the distributable component parts. This requires careful attention to the distribution potential of components early in the architectural design process.
- Reducing cost of maintenance and evolution: Architecture can help minimize the costs of maintaining and evolving a given system over its entire lifetime by anticipating the main kinds of changes that will occur in the system, ensuring that the system's overall design will facilitate such changes, and localizing as far as possible the effects of such changes on design documents, code, and other system work products. This can be achieved by the minimization and control of subsystem interdependencies.
- Increasing reuse and integration with legacy and third party software: An architecture may be designed to enable and facilitate the (re)use of certain existing components, frameworks, class libraries, legacy or third-party applications, etc.

2. Steps

The following steps are defined in the discipline of technical architecture:

- Forming a team structure
- Create a skeletal system
- Exploit patterns in an architecture
- Ensure conformance to an architecture
- Building domain-specific languages

3. Processes

There are two important processes defined in technical architecture. These processes will be clarified in the underlying text.

4. Technical Process

Technical Process is to be defined unambiguously. The main deliverable for a software architect is the architecture documentation, motivating and describing the structure of the system through various views. However, though system structuring forms a basis for the architectural design process, it is just one of several activities critical to the creation of a good architecture. In order to make such a deliverable to be able to instruct software developers, the following model can be used. First architectural requirements are needed to focus the structuring activities. These requirements are then input to produce Architecture specifications. At the end, a validation phase provides early indicators and opportunities to resolve problems with the architecture. The model contains an iterative part, indicating that the Architecture validation can be input for new requirements.

5. Requirements

Architectural requirements are a subset of the system requirements, determined by architectural relevance. The business objectives for the system and the architecture in particular, are important to ensure that the architecture is aligned with the business agenda. The system context helps determine what is in scope and what is out of scope, what the system interface is, and what factors impinge on the architecture. The system value proposition helps establish how the system will fit the users agenda and top-level, high-priority goals. These goals are translated into a set of use cases, which are used to document functional requirements. The system structure fails if it does not support the services or functionality that users value, or if the qualities associated with this functionality inhibit user performance or are otherwise unsatisfactory. System qualities that have architectural significance (e.g., performance and security, but not usability at the user interface level) are therefore also important in directing architectural choices during structuring. Requirements may already have been collected by product teams. In that case, the architecture team needs to review those requirements for architectural relevance and completeness (especially with respect to non-functional requirements), and be concerned with requirements for future products that the architecture will need to support. For the architecture of a product line or family, architectural requirements that are unique to each product and those that are common across the product set need to be distinguished so that the structure can be designed to support both the commonality and the uniqueness in each product.

6. Specification

The architecture is created and documented in the system structuring phase.

7. Meta-Architecture

First, the architectural vision is formulated, to act as a beacon guiding decisions during the rest of system structuring. It is a good practice to explicitly allocate time for research in documented architectural styles, patterns, dominant designs and reference architectures, other architectures your organization, competitors, partners, or suppliers have created or you find documented in the literature, etc. Based on this study, and your and the teams past experience, the meta-architecture is formulated. This includes the architectural style, concepts, mechanisms and principles that will guide the architecture team during the next steps of structuring.

8. Conceptual Architecture

The system is decomposed into components and the responsibilities of each component, and interconnections between components are identified. The intent of the conceptual architecture is to direct attention at an appropriate decomposition of the system without delving into the details of interface specification and type information. Moreover, it provides a useful vehicle for communicating the architecture to non-technical audiences, such as management, marketing, and many users.

9. Logical Architecture

The conceptual architecture forms the starting point for the logical architecture, and is likely to be modified as well as refined during the course of the creation of the logical architecture. Modeling the dynamic behavior of the system at the architectural level is a useful way to think through and refine the responsibilities and interfaces of the components. Component specifications including the following make the architecture concrete.

- A summary description of services the component provides
- The component owners name
- ID and version names
- Message signatures
- A description of the operations
- Constraints or pre-post conditions for each operation
- The concurrency model
- Constraints on component composition
- A lifecycle model
- How the component is instantiated
- How it is named
- A typical use scenario
- A programming example
- Exceptions
- A test or performance suite

10. Execution Architecture

Execution architecture is created for distributed or concurrent systems. It is formed by mapping the components onto the processes of the physical system. Different possible configurations are evaluated against requirements such as performance and scaling.

11. Architecture Tradeoff Analysis

At each step in structuring, it is worthwhile challenging the teams creativity to expand the solution set under consideration, and then evaluating the different architecture alternatives against the prioritized architectural requirements. This is known as architecture tradeoff analysis, and it recognizes that different approaches yield differing degrees of fit to the requirements. Selection of the best solution generally involves some compromise, but it is best to make this explicit.

12. Validation

During structuring, the architects obviously make their best effort to meet the requirements on the architecture. The architecture validation phase involves additional people from outside the architectural design team to help provide an objective assessment of the architecture. In addition to enhancing confidence that the architecture will meet the demands placed on it, including the right participants in this phase can help create buy-in to the architecture. Architecture assessment involves "thought experiments", modeling and walking-through scenarios that exemplify requirements, as well as assessment by experts who look for gaps and weaknesses in the architecture based on their experience. Another important part of validation is the development of prototypes or proofs-of-concept. Taking a skeletal version of the architecture all the way through to implementation, for example, is a really good way to prove out aspects of the architecture.

13. Organization Process

Overview

Architecture projects are susceptible to three major organizational sources of failure:

- The project is under-resourced or cancelled by an uncommitted management
- The project is stalled with infighting or a lack of leadership
- The architecture is ignored or resisted by project managers.

The organizational process helps address these pitfalls. Two phases namely Init/Commit and Deployment bookend the technical process. However, the principal activities in these phases, namely championing the architecture and leading/teaming in Init/Commit, and consulting in Deployment, also overlap with the technical process activities.

14. Initiate

The Initiate phase focuses on initiating the architecture project on a sound footing, and gaining strong commitment from upper management. The creation of the architecture vision is central both to aligning the architecture team and gaining management sponsorship. A communication plan is also helpful in sensitizing the team to the need for frequent communication with others in the organization. A heads-down, hidden skunkworks architecture project may make quick progress as long as it is well-led and its members act as a team. However, not listening to the needs of the management, developers, marketing, manufacturing and user communities and not paying attention to gaining and sustaining sponsorship in the management and technical leadership of the organization, or buy-in from the developer community, will lead to failure. The communication plan places attention on balancing the need for communication and isolation, as well as planning what to communicate when, and to whom.

15. Deployment

The Deployment phase follows the technical process, and addresses the needs of the developers who are meant to use the architecture to design and implement products. These range from understanding the architecture and its rationale, to responding to the need for changes to the architecture. This entails consulting, and perhaps tutorials and demos, as well as the architects' involvement in design reviews.

16. Championing

It is important that at least the senior architect and the architecture project manager (if there is one) champion the architecture and gain the support of all levels of management affected by the architecture. Championing the architecture starts early, and continues throughout the life of the architecture, though attention to championing tapers off as the architecture comes to be embraced by the management and developer communities.

17. Leading/Teaming

For the architecture team to be successful, there must be a leader and the team members must collaborate to bring their creativity and experience to bear on creating an architecture that will best serve the organization. This would seem so obvious as to not warrant being said, but unfortunately this is easier said than done. Explicit attention to developing the designated lead architects leadership skills, in the same way one would attend to developing these skills in management, is a worthy investment. Likewise, investing in activities aimed at developing the team as a team also has great payoff in the teams efficacy.

18. Communicating and Consulting

Consulting with and assisting the developer community in their use of the architecture is important in facilitating its successful adoption and appropriate use. These activities are most intense during deployment. However, earlier communication and consulting helps create buy-in the developer community through participation and understanding. This allows the architecture team to understand the developers needs and the developers to understand the architecture (and its rationale) as it evolves through the cycles of the technical process.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Concepts
- Understand the Philosophy of Mind

Definition/Overview:

Concept: A concept is typically associated with a corresponding representation in a language or symbology such as a word.

Key Points:

1. Concepts

Concepts are bearers of meaning, as opposed to agents of meaning. A vast array of accounts attempt to explain the nature of concepts. According to classical accounts, a concept denotes all of the entities, phenomena, and/or relations in a given category or class by using definitions. Concepts are abstract in that they omit the differences of the things in their extension, treating the members of the extension as if they were identical. Classical concepts are universal in that they apply equally to every thing in their extension. Concepts are also the basic elements of propositions, much the same way a word is the basic semantic element of a sentence. Unlike perceptions, which are particular images of individual objects, concepts cannot be visualized. Because they are not themselves individual perceptions, concepts are discursive and result from reason. Concepts are expected to be useful in dealing with reality. Generally speaking, concepts are taken to be (a) acquired dispositions to recognize perceived objects as being of this kind or of that ontological kind, and at the same time (b) to understand what this kind or that kind of object is like, and consequently (c) to perceive a number of perceived particulars as being the same in kind and to discriminate between them and other sensible particulars that are different in kind. In addition, concepts are acquired dispositions to understand what certain kinds of objects are like both (a) when the objects, though perceptible, are not actually perceived, and (b) also when they are not perceptible at all, as is the case with all the conceptual constructs we employ in physics, mathematics, and metaphysics. The impetus to have a theory of concepts that is ontologically useful has been so strong that it has pushed forward accounts that understand a concept to have a deep connection with reality. On some accounts, there may be agents (perhaps some animals) which don't think about, but rather use relatively basic concepts (such as demonstrative and perceptual concepts for things in their perceptual field), even though it is generally assumed that they do not think in symbols. On other accounts, mastery of symbolic thought (in particular, language) is a prerequisite for conceptual thought.

Concepts are bearers of meaning, as opposed to agents of meaning. A single concept can be expressed by any number of languages. The concept of DOG can be expressed as dog in English, Hund in German, as chien in French, and perro in Spanish. The fact that concepts are in some sense independent of language makes translation possible - words in various languages have identical meaning, because they express one and the same concept. A term labels or designates concepts. Several partly or fully distinct concepts may share the same term. These different concepts are easily confused by mistakenly being used interchangeably, which is a fallacy. Also, the concepts of term and concept are often confused, although the two are not the same. The acquisition of concepts is studied in machine learning as supervised classification and unsupervised classification, and in psychology and cognitive science as concept learning and category formation. In the philosophy of Kant, any purely empirical theory dealing with the acquisition of concepts is referred to as a noogony.

2. Philosophy of Mind

Philosophy of mind is the branch of philosophy that studies the nature of the mind, mental events, mental functions, mental properties, consciousness and their relationship to the physical body, particularly the brain. The mind-body problem, i.e. the relationship of the mind to the body, is commonly seen as the central issue in philosophy of mind, although there are other issues concerning the nature of the mind that do not involve its relation to the physical body. Dualism and monism are the two major schools of thought that attempt to resolve the mind-body problem. Dualism can be traced back to Plato, Aristotle and the Sankhya and Yoga schools of Hindu philosophy, but it was most precisely formulated by Ren Descartes in the 17th century. Substance Dualists argue that the mind is an independently existing substance, whereas Property Dualists maintain that the mind is a group of independent properties that emerge from and cannot be reduced to the brain, but that it is not a distinct substance. Monism is the position that mind and body are not ontologically distinct kinds of entities. This view was first advocated in Western Philosophy by Parmenides in the 5th century BC and was later espoused by the 17th century rationalist Baruch Spinoza. Physicalists argue that only the entities postulated by physical theory exist, and that the mind will eventually be explained in terms of these entities as physical theory continues to evolve. Idealists maintain that the mind is all that exists and that the external world is either mental itself, or an illusion created by the mind. Neutral monists adhere to the position that there is some other, neutral substance, and that both matter and mind are properties of this unknown substance. The most common monisms in the 20th and 21st centuries have all been variations of physicalism; these positions include behaviorism, the type identity theory, anomalous monism and functionalism.

Most modern philosophers of mind adopt either a reductive or non-reductive physicalist position, maintaining in their different ways that the mind is not something separate from the body. These approaches have been particularly influential in the sciences, especially in the fields of sociobiology, computer science, evolutionary psychology and the various neurosciences. Other philosophers, however, adopt a non-physicalist position which challenges the notion that the mind is a purely physical construct. Reductive physicalists assert that all mental states and properties will eventually be explained by scientific accounts of physiological processes and states. Non-reductive physicalists argue that although the brain is all there is to the mind, the predicates and vocabulary used in mental descriptions and explanations are indispensable, and cannot be reduced to the language and lower-level explanations of physical science. Continued neuroscientific progress has helped to clarify some of these issues. However, they are far from having been resolved, and modern philosophers of mind continue to ask how the subjective qualities and the intentionality (aboutness) of mental states and properties can be explained in naturalistic terms.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Concept
- Understand the A Posteriori Abstractions
- Learn about the Priori Concepts

Definition/Overview:

Concept: As the term is used in mainstream cognitive science and philosophy of mind, a concept or conception is an abstract idea or a mental symbol, typically associated with a corresponding representation in a language or symbology.

Key Points:

1. A Posteriori Abstractions

John Locke's description of a general idea corresponds to a description of a concept. According to Locke, a general idea is created by abstracting, drawing away, or removing the common characteristic or characteristics from several particular ideas. This common characteristic is that which is similar to all of the different individuals. For example, the abstract general idea or concept that is designated by the word "red" is that characteristic which is common to apples, cherries, and blood. The abstract general idea or concept that is signified by the word "dog" is the collection of those characteristics which are common to Airedales, Collies, and Chihuahuas. In the same tradition as Locke, John Stuart Mill stated that general conceptions are formed through abstraction. A general conception is the common element among the many images of members of a class. When we form a set of phenomena into a class, that is, when we compare them with one another to ascertain in what they agree, some general conception is implied in this mental operation. Mill did not believe that concepts exist in the mind before the act of abstraction. "It is not a law of our intellect, that, in comparing things with each other and taking note of their agreement, we merely recognize as realized in the outward world something that we already had in our minds. The conception originally found its way to us as the result of such a comparison. It was obtained (in metaphysical phrase) by abstraction from individual things.

For Schopenhauer, empirical concepts are mere abstractions from what is known through intuitive perception, and they have arisen from our arbitrarily thinking away or dropping of some qualities and our retention of others. In his On the Will in Nature, "Physiology and Pathology," Schopenhauer said that a concept is "drawn off from previous images ... by putting off their differences. This concept is then no longer intuitively perceptible, but is denoted and fixed merely by words." Nietzsche, who was heavily influenced by Schopenhauer, wrote: "Every concept originates through our equating what is unequal. No leaf ever wholly equals another, and the concept 'leaf' is formed through an arbitrary abstraction from these individual differences, through forgetting the distinctions".

A concept is a common feature or characteristic. Kant investigated the way that empirical a posteriori concepts are created. The logical acts of the understanding by which concepts are generated as to their form are: (1.) comparison, i.e., the likening of mental images to one another in relation to the unity of consciousness; (2.) reflection, i.e., the going back over different mental images, how they can be comprehended in one consciousness; and finally (3.) abstraction or the segregation of everything else by which the mental images differ. In order to make our mental images into concepts, one must thus be able to compare, reflect, and abstract, for these three logical operations of the understanding are essential and general conditions of generating any concept whatever. For example, I see a fir, a willow, and a linden. In firstly comparing these objects, I notice that they are different from one another in respect of trunk, branches, leaves, and the like; further, however, I reflect only on what they have in common, the trunk, the branches, the leaves themselves, and abstract from their size, shape, and so forth. Kant's description of the making of a concept has been paraphrased as " to conceive is essentially to think in abstraction what is common to a plurality of possible instances . In his discussion of Kant, Christopher Janaway wrote: " generic concepts are formed by abstraction from more than one species."

2. A Priori Concepts

Kant declared that human minds possess pure or a priori concepts. Instead of being abstracted from individual perceptions, like empirical concepts, they originate in the mind itself. He called these concepts categories, in the sense of the word that means predicate, attribute, characteristic, or quality. But these pure categories are predicates of things in general, not of a particular thing. According to Kant, there are 12 categories that constitute the understanding of phenomenal objects. Each category is that one predicate which is common to multiple empirical concepts. In order to explain how an a priori concept can relate to individual phenomena, in a manner analogous to an a posteriori concept, Kant employed the technical concept of the schema.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Concept
- Understand the Content as Pragmatic Role
- Understand the Embodied Content
- Learn about the Philosophical Implications

Definition/Overview:

Concept: Concept has also been defined as a unit of knowledge built from characteristics.

Key Points:

1. Content as Pragmatic Role

A concept may be abstracted from several perceptions, but that is only its origin. In regard to its meaning or its truth, William James proposed his Pragmatic Rule. This rule states that the meaning of a concept may always be found in some particular difference in the course of human experience which its being true will make (Some Problems of Philosophy, "Percept and Concept The Import of Concepts"). In order to understand the meaning of the concept and to discuss its importance, a concept may be tested by asking, "What sensible difference to anybody will its truth make?" There is only one criterion of a concept's meaning and only one test of its truth. That criterion or test is its consequences for human behavior. In this way, James bypassed the controversy between rationalists and empiricists regarding the origin of concepts. Instead of solving their dispute, he ignored it. The rationalists had asserted that concepts are a revelation of Reason. Concepts are a glimpse of a different world, one which contains timeless truths in areas such as logic, mathematics, ethics, and aesthetics. By pure thought, humans can discover the relations that really exist among the parts of that divine world. On the other hand, the empiricists claimed that concepts were merely a distillation or abstraction from perceptions of the world of experience. Therefore, the significance of concepts depends solely on the perceptions that are its references. James's Pragmatic Rule does not connect the meaning of a concept with its origin. Instead, it relates the meaning to a concept's purpose, that is, its function, use, or result.

2. Embodied Content

In Cognitive linguistics, abstract concepts are transformations of concrete concepts derived from embodied experience. The mechanism of transformation is structural mapping, in which properties of two or more source domains are selectively mapped onto a blended space. A common class of blends is metaphors. This theory contrasts with the rationalist view that concepts are perceptions (or recollections, in Plato's term) of an independently existing world of ideas, in that it denies the existence of any such realm. It also contrasts with the empiricist view that concepts are abstract generalizations of individual experiences, because the contingent and bodily experience is preserved in a concept, and not abstracted away. While the perspective is compatible with Jamesian pragmatism (above), the notion of the transformation of embodied concepts through structural mapping makes a distinct contribution to the problem of concept formation.

3. Philosophical Implications

Concepts and metaphilosophy

A long and well-established tradition in philosophy posits that philosophy itself is nothing more than conceptual analysis. This view has its proponents in contemporary literature as well as historical. According to Deleuze and Guattari's What Is Philosophy? (1991), philosophy is the activity of creating concepts. This creative activity differs from previous definitions of philosophy as simple reasoning, communication or contemplation of Universals. Concepts are specific to philosophy: science has got "percepts", and art "affects". A concept is always signed: thus, Descartes' Cogito or Kant's "transcendental". It is a singularity, not an universal, and connects itself with others concepts, on a "plane of immanence" traced by a particular philosophy. Concepts can jump from one plane of immanence to another, combining with other concepts and therefore engaging in a "becoming-Other."

4. Concepts in epistemology

Concepts are vital to the development of scientific knowledge. For example, it would be difficult to imagine physics without concepts like: energy, force, or acceleration. Concepts help to integrate apparently unrelated observations and phenomena into viable hypothesis and theories, the basic ingredients of science. The concept map is a tool that is used to help researchers visualize the inter-relationships between various concepts.

5. Ontology of concepts

Although the mainstream literature in cognitive science regards the concept as a kind of mental particular, it has been suggested by some theorists that concepts are real things. In most radical form, the realist about concepts attempts to show that the supposedly mental processes are not mental at all; rather, they are abstract entities, which are just as real as any mundane object. Plato was the starkest proponent of the realist thesis of universal concepts. By his view, concepts (and ideas in general) are innate ideas that were instantiations of a transcendental world of pure forms that lay behind the veil of the physical world. In this way, universals were explained as transcendent objects. Needless to say this form of realism was tied deeply with Plato's ontological projects. This remark on Plato is not of merely historical interest. For example, the view that numbers are Platonic objects was revived by Kurt Godel as a result of certain puzzles that he took to arise from the phenomenological accounts. Gottlob Frege, founder of the analytic tradition in philosophy, famously argued for the analysis of language in terms of sense and reference. For him, the sense of an expression in language describes a certain state of affairs in the world, namely, the way that some object is presented. Since many commentators view the notion of sense as identical to the notion of concept, and Frege regards senses as the linguistic representations of states of affairs in the world, it seems to follow that we may understand concepts as the manner in which we grasp the world. Accordingly, concepts (as senses) have an ontological status.

According to Carl Benjamin Boyer, in the introduction to his The History of the Calculus and its Conceptual Development, concepts in calculus do not refer to perceptions. As long as the concepts are useful and mutually compatible, they are accepted on their own. For example, the concepts of the derivative and the integral are not considered to refer to spatial or temporal perceptions of the external world of experience. Neither are they related in any way to mysterious limits in which quantities are on the verge of nascence or evanescence that is, coming into or going out of appearance or existence. The abstract concepts are now considered to be totally autonomous, even though they originated from the process of abstracting or taking away qualities from perceptions until only the common, essential attributes remained.

In Section 4 of this course you will cover these topics:

- Modeling Of Product Metrics
- Design For Manufacture And Assembly
- Design For The Environment
- Analytical And Numerical Model Solutions

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Metric
- Understand the Product and Market
- Learn about the Manufacturing

Definition/Overview:

Product: In marketing, a product is anything that can be offered to a market that might satisfy a want or need. In retailing, products are called merchandise.

Metric: A metric is a standard unit of measure, such as mile or second, or more generally, part of a system of parameters, or systems of measurement, or a set of ways of quantitatively and periodically measuring, assessing, controlling or selecting a person, process, event, or institution, along with the procedures to carry out measurements and the procedures for the interpretation of the assessment in the light of previous or comparable assessments.

Key Points:

1. Metric

Metrics are usually specialized by the subject area, in which case they are valid only within a certain domain and cannot be directly benchmarked or interpreted outside it. This factor severely limits the applicability of metrics, for instance in comparing performance across domains. The prestige attached to them may be said to relate to a 'quantifiability fallacy', the erroneous belief that if a conclusion is reached by quantitative measurement, it must be vindicated, irrespective of what parameters or purpose the investigation is supposed to have. Examples include academic metrics such as an academic journal's impact factor and bibliometrics; crime statistics; corporate investment metrics, such as earnings per share or Price-to-earnings ratio; economic metrics or economic indicators, such as gross domestic product and the Gini coefficient, which are the subject of econometrics; education metrics, such as grade point average, standardized test scores such as the SAT and College and university rankings; environmental or sustainability metrics and indices; health metrics, such as mortality rate and life expectancy; market metrics such as the Q score; political metrics, such as the United States Presidential approval rating; software metrics; and vehicle metrics such as miles per gallon. In business, they are sometimes referred to as key performance indicators, such as overall equipment effectiveness, or key risk indicators. In the field of Facilities Management, a key metric is the Facility Condition Index, or FCI.

2. Product and Market

In marketing, a product is anything that can be offered to a market that might satisfy a want or need. In retailing, products are called merchandise. In manufacturing, products are purchased as raw materials and sold as finished goods. Commodities are usually raw materials such as metals and agricultural products, but a commodity can also be anything widely available in the open market. The verb produce (prə doos’ or -dyoos’) is from the Latin prōdūce(re), (to) lead or bring forth. The noun product (prod'əkt or-ukt) is "a thing produced by labor or effort". Since 1575, the word "product" has referred to anything produced. Since 1695, the word has referred to "thing or things produced". The economic or commercial meaning of product was first used by political economist Adam Smith. In general usage, product may refer to a single item or unit, a group of equivalent products, a grouping of goods or services, or an industrial classification for the goods or services.

3. Manufacturing

Manufacturing is the use of machines, tools and labor to make things for use or sale. The term may refer to a range of human activity, from handicraft to high tech, but is most commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale. Such finished goods may be used for manufacturing other, more complex products, such as household appliances or automobiles, or sold to wholesalers, who in turn sell them to retailers, who then sell them to end users - the "consumers". Manufacturing takes place under all types of economic systems. In a free market economy, manufacturing is usually directed toward the mass production of products for sale to consumers at a profit. In a collectivist economy, manufacturing is more frequently directed by the state to supply a centrally planned economy. In free market economies, manufacturing occurs under some degree of government regulation. Modern manufacturing includes all intermediate processes required for the production and integration of a product's components. Some industries, such as semiconductor and steel manufacturers use the term fabrication instead.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Design for Assembly
- Understand the Implementation

Definition/Overview:

Design for Assembly: Design for Assembly is a process by which products are designed with ease of assembly in mind. If a product contains fewer parts it will take less time to assemble, thereby reducing assembly costs. In addition, if the parts are provided with features which make it easier to grasp, move, orient and insert them, this will also reduce assembly time and assembly costs. The reduction of the number of parts in an assembly has the added benefit of generally reducing the total cost of parts in the assembly. This is usually where the major cost benefits of the application of design for assembly occur.

Key Points:

1. Approaches to Design for Assembly

Design for assembly can take different forms. In the 1960s and 70's various rules and recommendations were proposed in order to help designers consider assembly problems during the design process. Many of these rules and recommendations were presented together with practical examples showing how assembly difficulty could be improved. However, it was not until the 1970s that numerical evaluation methods were developed to allow design for assembly studies to be carried out on existing and proposed designs. The first evaluation method was developed at Hitachi and was called the Assembly Evaluation Method (AEM).This method is based on the principle of "one motion for one part." For more complicated motions, a point-loss standard is used and the ease of assembly of the whole product is evaluated by subtracting points lost. The method was originally developed in order to rate assemblies for ease of automatic assembly. Starting in 1977, Geoff Boothroyd, supported by an NSF grant at the University of Massachusetts, developed the Design for Assembly method (DFA), which could be used to estimate the time for manual assembly of a product and the cost of assembling the product on an automatic assembly machine. Recognizing that the most important factor in reducing assembly costs was the minimization of the number of separate parts in a product, he introduced three simple criteria which could be used to determine theoretically whether any of the parts in the product could be eliminated or combined with other parts. These criteria, together with tables relating assembly time to various design factors influencing part grasping, orientation and insertion, could be used to estimate total assembly time and to rate the quality of a product design from an assembly viewpoint. For automatic assembly, tables of factors could be used to estimate the cost of automatic feeding and orienting and automatic insertion of the parts on an assembly machine. In the 1980s and 90's variations of the AEM and DFA methods have been proposed, namely: the GE Hitachi method which is based on the AEM and DFA; the Lucas method, the Westinghouse method and several others which were based on the original DFA method. All methods are now referred to as Design for Assembly methods.

2. Implementation

Most products are assembled manually and the original DFA method for manual assembly is the most widely used method and has had the greatest industrial impact throughout the world. The DFA method, like the AEM method, was originally made available in the form of a handbook where the user would enter data on worksheets to obtain a rating for the ease of assembly of a product. Starting in 1981, Geoffrey Boothroyd and Peter Dewhurst developed a computerized version of the DFA method which allowed its implementation in a broad range of companies. For this work they were presented with many awards including the National Medal of Technology. There are many published examples of significant savings obtained through the application of DFA. For example in 1981, Sidney Liebson, manager of manufacturing engineering for Xerox, estimated that his company would save hundreds of millions of dollars through the application of DFA. In 1988, Ford Motor Company credited the software with overall savings approaching $1 billion. In many companies DFA is a corporate requirement and DFA software is continually being adopted by companies attempting to obtain greater control over their manufacturing costs.

3. Notable examples of design for assembly

Two notable examples of good design for assembly are the Sony Walkman and the Swatch watch. Both were designed for fully automated assembly. The Walkman line was designed for "vertical assembly", in which parts are inserted in straight-down moves only. The Sony SMART assembly system, used to assemble Walkman-type products, is a robotic system for assembling small devices designed for vertical assembly.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Environmental Design
- Understand the Efficient Energy
- Learn about the New Urbanism

Definition/Overview:

Environmental Design: Environmental design is the process of addressing environmental parameters when devising plans, programs, policies, buildings, or products. Classical prudent design may have always considered environmental factors; however, the environmental movement beginning in the 1960s has made the concept more explicit.

Key Points:

1. Environmental Design

Environmental Design has been defined as we live in the world by design. Creating the everyday environment in which we live involves complex systems of cultural meaning, visual communication and the use of tools, technology and materials. As a field of study, Environmental Design encompasses the built, natural, and human environments and focuses on fashioning physical and social interventions informed by human behavior and environmental processes. Design asks us to find answers to the most fundamental of human questions: how should we live in the world and what should inform our actions? This complex endeavor requires an interdisciplinary approach."

Environmental design in the old-fashioned sense develops physical environments, both interior and exterior, to meet one or more aesthetic or day-to-day functional needs, or to create a specific sort of experience - the focus being the human-designed environment. Environmental design includes such specialties as architects, acoustical scientists, engineers, environmental scientists, landscape architects, urban planning, interior designers, lighting designers, and exhibition designers. In many situations, historic preservation can be added to this list. Another recent addition to this general area might be "disability access". In terms of a larger scope, environmental design has implications for the industrial design of products: innovative automobiles, wind-electricity generators, solar-electric equipment, and other kinds of equipment could serve as examples. Examples of the environmental design process include use of roadway noise computer models in design of noise barriers and use of roadway air dispersion models in analyzing and designing urban highways. Designers consciously working within this more recent framework of philosophy and practice seek a blending of nature and technology, regarding ecology as the basis for design. Some believe that strategies of conservation, stewardship, and regeneration can be applied at all levels of scale from the individual building to the community, with benefit to the human individual and local and planetary ecosystems.

Specific examples of large scale environmental design projects include:

- Boston Transportation Planning Review
- Bay Area Rapid Transit System Daly City Turnback project and airport extension.
- Metropolitan Portland, Oregon light rail system

Early roots began in the late 19th Century with writer/designer William Morris, who rejected the use of industrialized materials and processes in wallpaper, fabrics and books his studio produced. He and others, such as John Ruskin felt that the industrial revolution would lead to harm done to nature and workers. From the middle of the twentieth century, thinkers like Buckminster Fuller have acted as catalysts for a broadening and deepening of the concerns of environmental designers. Nowadays, energy efficiency, appropriate technology, organic horticulture or organic agriculture, land restoration, community design, and ecologically sustainable energy and waste systems are recognized considerations or options and may each find application.

2. Efficient Energy

Efficient energy use, sometimes simply called energy efficiency, is using less energy to provide the same level of energy service. An example would be insulating a home to use less heating and cooling energy to achieve the same temperature. Another example would be installing fluorescent lights and/or skylights instead of incandescent lights to attain the same level of illumination. Efficient energy use is achieved primarily by means of a more efficient technology or process rather than by changes in individual behavior.

3. New Urbanism

New Urbanism is an urban design movement that arose in the United States in the early 1980s. Its goal is to reform many aspects of real estate development and urban planning, from urban retrofits to suburban infill. New urbanist neighborhoods are designed to contain a diverse range of housing and jobs, and to be walkable. New Urbanism can include (neo) traditional neighborhood design, transit-oriented development, and New Pedestrianism. New Urbanism is the re-invention of the old urbanism, commonly seen before the advent of the automobile age, while New Pedestrianism is a further elaboration of less common, pedestrian-oriented, urban design experiments that date to the early 20th century.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Numerical Model
- Understand the Modern Method

Definition/Overview:

Computational model: Computational model is a mathematical model in computational science that requires extensive computational resources to study the behavior of a complex system by computer simulation.

Analytical models: Analytical models are mathematical models that have a closed form solution, i.e. the solution to the equations used to describe changes in a system can be expressed as a mathematical analytic function.

Key Points:

1. Numerical Model

A numerical model of the solar system is a set of mathematical equations, which, when solved, give the approximate positions of the planets as a function of time. Attempts to create such a model established the more general field of celestial mechanics. The results of this simulation can be compared with past measurements to check for accuracy and then be used to predict future positions. Its main use therefore is in preparation of almanacs.

The simulations can be done in either Cartesian or in spherical coordinates. The former are easier, but extremely calculation intensive, and only doable on an electronic computer. As such only the latter was used in former times. Strictly speaking not much less calculation intensive, but it was possible to start with some simple approximations and then to add perturbations, as much as needed to reach the wanted accuracy. In essence this mathematical simulation of the solar system is a form of the N-body problem. The symbol N represents the number of bodies, which can grow quite large if one includes 1 sun, 8 planets, dozens of moons and countless planetoids, comets and so forth. However the influence of the sun on any other body is so large, and the influence of all the other bodies on each other so small that the problem can be reduced to the analytically solvable 2-body problem. The result for each planet is an orbit, a simple description of its position as function of time. Once this is solved the influences moons and planets have on each other are added as small corrections. (Small compared to a full planetary orbit, some corrections might be still several degrees large, while measurements can be made to an accuracy of better than 1″). Although this method is no longer used for simulations, it is still useful to find an approximate ephemeris as one can take the relatively simple main solution, perhaps add a few of the largest perturbations, and arrive without too much effort at the wanted planetary position. The disadvantage is that perturbation theory is very advanced mathematics.

2. Modern Method

The modern method consists of numerical integration in 3-dimensional space. One starts with a high accuracy value for the position (x, y, z) and the velocity (vx, vy, vz) for each of the bodies involved. When also the mass of each body is known, the acceleration (ax, ay, az) can be calculated from Newton's Law of Gravitation. Each body attracts each other body, the total acceleration being the sum of all these attractions. Next one chooses a small timestep Δt and applies Newton’s Second Law of Motion. The acceleration multiplied with Δt gives a correction to the velocity. The velocity multiplied with Δt gives a correction the position. This procedure is repeated for all other bodies. The result is a new value for position and velocity for all bodies. Then, using these new values one starts over the whole calculation for the next timestep Δt. Repeating this procedure often enough, and one ends up with a description of the positions of all bodies over time. The advantage of this method is that for a computer it is a very easy job to do, and it yields highly accurate results for all bodies at the same time, doing away with the complex and difficult procedures for determining perturbations. The disadvantage is that one must start with highly accurate figures in the first place, or the results will drift away from the reality in time; that one gets x, y, z positions which are often first to be transformed into more practical ecliptical or equatorial coordinates before they can be used; and that it is an all or nothing approach. If one wants to know the position of one planet on one particular time, then all other planets and all intermediate timesteps are to be calculated too.

In Section 5 of this course you will cover these topics:

- Physical Prototypes
- Physical Models And Experimentation
- Design For Robustness

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Semantics

- Understand the Design and Modeling

Definition/Overview:

Prototype: A prototype is an original type, form, or instance of something serving as a typical example, basis, or standard for other things of the same category.

Key Points:

1. Semantics

In semantics, prototypes or proto instances combine the most representative attributes of a category. Prototypes are typical instances of a category that serve as benchmarks against which the surrounding, less representative instances are categorized. Semantics is the study of meaning in communication. The word is derived from the Greek word σημαντικός (semantikos), "significant", from σημαίνω (semaino), "to signify, to indicate" and that from σήμα (sema), "sign, and mark, token". In linguistics, it is the study of interpretation of signs as used by agents or communities within particular circumstances and contexts. It has related meanings in several other fields. Semanticists differ on what constitutes meaning in an expression. For example, in the sentence, "John loves a bagel", the word bagel may refer to the object itself, which is its literal meaning or denotation, but it may also refer to many other figurative associations, such as how it meets John's hunger, etc., which may be its connotation. Traditionally, the formal semantic view restricts semantics to its literal meaning, and relegates all figurative associations to pragmatics, but many find this distinction difficult to defend. The degree to which a theorist subscribes to the literal-figurative distinction decreases as one moves from the formal semantic, semiotic, pragmatic, to the cognitive semantic traditions. The word semantic in its modern sense is considered to have first appeared in French as smantique in Michel Bral's 1897 book, Essai de smantique'. In International Scientific Vocabulary semantics is also called semasiology. The discipline of Semantics is distinct from Alfred Korzybski's General Semantics, which is a system for looking at the semantic reactions of the whole human organism in its environment to some event, symbolic or otherwise.

2. Design and Modeling

In many fields, there is great uncertainty as to whether a new design will actually do what is desired. New designs often have unexpected problems. A prototype is often used as part of the product design process to allow engineers and designers the ability to explore design alternatives, test theories and confirm performance prior to starting production of a new product. Engineers use their experience to tailor the prototype according to the specific unknowns still present in the intended design. For example, some prototypes are used to confirm and verify consumer interest in a proposed design where as other prototypes will attempt to verify the performance or suitability of a specific design approach. In many product development organizations, prototyping specialists are employed - individuals with specialized skills and training in general fabrication techniques that can help bridge between theoretical designs and the fabrication of prototypes. There is no general agreement on what constitutes a "prototype" and the word is often used interchangeably with the word "model" which can cause confusion. In general, prototypes fall into four basic categories: Proof-of-Principle Prototype (Model) (also called a breadboard). This type of prototype is used to test some aspect of the intended design without attempting to exactly simulate the visual appearance, choice of materials or intended manufacturing process. Such prototypes can be used to prove out a potential design approach such as range of motion, mechanics, sensors, architecture, etc. These types of models are often used to identify which design options will not work, or where further development and testing is necessary.

Form Study Prototype (Model). This type of prototype will allow designers to explore the basic size, look and feel of a product without simulating the actual function or exact visual appearance of the product. They can help assess ergonomic factors and provide insight into visual aspects of the product's final form. Form Study Prototypes are often hand-carved or machined models from easily sculpted, inexpensive materials (e.g., urethane foam), without representing the intended color, finish, or texture. Due to the materials used, these models are intended for internal decision making and are generally not durable enough or suitable for use by representative users or consumers. Visual Prototype (Model) will capture the intended design aesthetic and simulate the color and surface textures of the intended materials. These models will be suitable for use in market research, packaging mock-ups, and photo shoots for sales literature.

Functional Prototype (Model) (also called a working prototype) will, to the greatest extent practical, attempt to simulate the final design, aesthetics, materials and functionality of the intended design. The construction of a fully working full-scale prototype and the ultimate test of concept, is the engineers' final check for design flaws and allows last-minute improvements to be made before larger production runs are ordered. In general, prototypes will differ from the final production variant in three fundamental ways: Prototypes are often constructed via non-production intent materials. Production materials may require manufacturing processes involving higher capital costs than what is practical for prototyping. Instead, engineers of prototyping specialists will attempt to substitute materials with properties that simulate the intended final material. Prototypes are generally constructed via non-production intent manufacturing processes. Often expensive and time consuming unique tooling is required to fabricate a custom designs. Prototypes will often compromise by using more flexible processes. Prototypes are generally constructed from a design that has been developed to a lower level of fidelity than production intent. Final production designs often require extensive effort to capture high volume manufacturing detail. Such detail is generally unwarranted for prototypes as some refinement to the design is to be expected. Often prototypes are built using very limited engineering detail as compared to final production intent. Engineers and prototyping specialists seek to understand the limitations of prototypes to exactly simulate the characteristics of their intended design. A degree of skill and experience is necessary to effectively use prototyping as a design verification tool. It is important to realize that by their very definition, prototypes will represent some compromise from the final production design. Due to differences in materials, processes and design fidelity, it is possible that a prototype may fail to perform acceptably whereas the production design may have been sound. A counter-intuitive idea is that prototypes may actually perform acceptably whereas the production design may be flawed since prototyping materials and processes may occasionally outperform their production counterparts. It is possible to use prototype testing to reduce the risk that a design may not perform acceptably, however prototypes generally cannot eliminate all risk. There are pragmatic and practical limitations to the ability of a prototype to match the intended final performance of the product and some allowances and engineering judgment are often required before moving forward with a production design.

Building the full design is often expensive and can be time-consuming, especially when repeated several times building the full design, figuring out what the problems are and how to solve them, then building another full design. As an alternative, "rapid-prototyping" or "rapid application development" techniques are used for the initial prototypes, which implement part, but not all, of the complete design. This allows designers and manufacturers to rapidly and inexpensively test the parts of the design that are most likely to have problems, solve those problems, and then build the full design. This counter-intuitive idea that the quickest way to build something is, first to build something else is shared by scaffolding and the telescope rule.

3. Mechanical and Electrical Engineering

The most common use of the word prototype is a functional, although experimental, version of a non-military machine (e.g., automobiles, domestic appliances, consumer electronics) whose designers would like to have built by mass production means, as opposed to a mockup, which is an inert representation of a machine's appearance, often made of some non-durable substance.
An electronics designer often builds the first prototype from breadboard or stripboard or perfboard, typically using "DIP" packages. However, more and more often the first functional prototype is built on a "prototype PCB" almost identical to the production PCB, as PCB manufacturing prices fall and as many components are not available in DIP packages, but only available in SMT packages optimized for placing on a PCB.
Builders of military machines and aviation prefer the terms "experimental" and "service test".

4. Computer Programming/Computer Science

In many programming languages, a function prototype is the declaration of a subroutine or function. (This term is rather C/C++-specific; other terms for this notion are signature, type and interface.) In prototype-based programming (a form of object-oriented programming), new objects are produced by cloning existing objects, which are called prototypes. The term may also refer to the Prototype JavaScript Framework.

Prototype software is often referred to as alpha grade, meaning it is the first version to run. Often only a few functions are implemented; the primary focus of the alpha is to have a functional base code on to which features may be added. Once alpha grade software has most of the required features integrated into it, it becomes beta software for testing of the entire software and to adjust the program to respond correctly during situations unforeseen during development. Often the end users may not be able to provide a complete set of application objectives, detailed input, processing, or output requirements in the initial stage. After the user evaluation, another prototype will be built based on feedback from users, and again the cycle returns to customer evaluation. The cycle starts by listening to the user, followed by building or revising a mock-up, and letting the user test the mock-up, then back. There is now a new generation of tools called Application Simulation Software which help quickly simulate application before their development. Extreme programming uses iterative design to gradually add one feature at a time to the initial prototype, attempting to minimize "irreducible complexity". Continuous learning approaches within organizations or businesses may also use the concept of business or process prototypes through software models.

5. Computer Engineering

In computer engineering, a prototype generally refers either to a breadboard (or evolutionary) prototype or a throwaway (or one-off) prototype. Breadboard prototypes are often simple in a development stage, focusing on a subset of the total requirements for a product. These prototypes usually are intended to evolve into the final design. Project managers may formally identify a component as prototype to communicate with stakeholders that the component may or may not comprise the techniques ultimately allocated to the product design, or to meet business objectives. It should not be assumed that the prototype is merely for testing concepts (throwaway). That would be an aspect of a "research" project or "proof of concept." Prototypes provide the developers with a "working model" for demonstration or use by customers, quality-assurance, business analysts, and managers to confirm or make changes to requirements, help define interfaces, develop collaborating components, and to provide proof of incremental achievement of scheduled contractual agreements.

6. Electronics prototyping

In electronics, prototyping means building an actual circuit to a theoretical design to verify that it works, and to provide a physical platform for debugging it if it does not. The prototype is often constructed using techniques such as wire wrap or using veroboard or breadboard, that create an electrically correct circuit, but one that is not physically identical to the final product.

A technician can build a prototype (and make additions and modifications) much quicker with these techniques however, it is much faster and usually cheaper to mass produce custom printed circuit boards than these other kinds of prototype boards. This is for the same reasons that writing a poem is fastest by hand for one or two, but faster by printing press if you need several thousand copies.

The proliferation of quick-turn pcb fab companies and quick-turn pcb assembly houses has enabled the concepts of rapid prototyping to be applied to electronic circuit design. It is now possible, even with the smallest passive components and largest fine-pitch packages, to have boards fabbed and parts assembled in a matter of days.

7. Scale modeling

In the field of scale modeling (which includes model railroading, vehicle modeling, airplane modeling, military modeling, etc.), a prototype is the real-world basis or source for a scale model such as the real EMD GP38-2 locomotive which is the prototype of Athearn's (among other manufacturers) locomotive model. Technically, any non-living object can serve as a prototype for a model, including structures, equipment, and appliances, and so on, but generally prototypes have come to mean full-size real-world vehicles including automobiles (the prototype 1957 Chevy has spawned many models), military equipment (such as M4 Shermans, a favorite among US Military modelers), railroad equipment, motor trucks, motorcycles, airplanes, and space-ships (real-world such as Apollo/Saturn Vs, or the ISS). There is debate whether 'fictional' or imaginary items can be considered prototypes (such as Star Wars or Star Trek starships, since the feature ships themselves are models or CGI-artifacts); however, humans and other living items are never called prototypes, even when they are the basis for models and dolls (especially - action figures). As of 2005, conventional rapid prototype machines cost around 25,000.

8. Metrology

In the science and practice of metrology, a prototype is a human-made object that is used as the standard of measurement of some physical quantity to base all measurement of that physical quantity against. Sometimes this standard object is called an artifact. In the International System of Units (SI), the only prototype remaining in current use is the International Prototype Kilogram, a solid platinum-iridium cylinder kept at the Bureau International des Poids et Mesures (International Bureau of Weights and Measures) in Paris (more precisely in Svres) that, by definition is the mass of exactly one kilogram. Copies of this prototype are fashioned and issued to many nations to represent the national standard of the kilogram and are periodically compared to the Paris prototype. Until 1960, the meter was defined by a platinum-iridium prototype bar with two scratch marks on it (that were, by definition, spaced apart by one meter), the International Prototype Meter, and in 1983 the meter was redefined to be the distance covered by light in 1/299,792,458 of a second (thus defining the speed of light to be 299,792,458 meters per second). It is widely believed that the kilogram prototype standard will be replaced by a definition of the kilogram that will define another physical constant (likely either Planck's constant or the elementary charge) to a defined constant, thus obviating the need for the prototype and removing the possibility of the prototype (and thus the standard and definition of the kilogram) changing very slightly over the years because of loss or gain of atoms.

9. Pathology

In pathology, prototype refers to a disease, virus, etc which sets a good example for the whole category. For example, the vaccina virus is regarded as the virus prototype of poxviridae.

Advantages and disadvantages

Advantages of prototyping

- May provide the proof of concept necessary to attract funding
- Early visibility of the prototype gives users an idea of what the final system looks like
- Encourages active participation among users and producer
- Enables a higher output for user
- Cost effective (Development costs reduced)
- Increases system development speed
- Assists to identify any problems with the efficacy of earlier design, requirements analysis and coding activities
- Helps to refine the potential risks associated with the delivery of the system being developed
- Various aspects can be tested and quicker feedback can be got from the user
- Helps to deliver the product in quality easily

Disadvantages of prototyping

- Producer might produce a system inadequate for overall organization needs
- User can get too involved whereas the program can not be to a high standard
- Structure of system can be damaged since many changes could be made
- Producer might get too attached to it (might cause legal involvement)
- Not suitable for large applications

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Physical Model
- Understand the Solar System
- Learn about the Model Organism

Definition/Overview:

Physical model: A physical model is a smaller or larger physical copy of an object. The object being modelled may be small (for example, an atom) or large (for example, the Solar System).

Key Points:

1. Physical model

The geometry of the model and the object it represents are often similar in the sense that one is a rescaling of the other; in such cases the scale is an important characteristic. However, in many cases the similarity is only approximate or even intentionally distorted. Sometimes the distortion is systematic with e.g. a fixed scale horizontally and a larger fixed scale vertically when modeling topography of a large area (as opposed to a model of a smaller mountain region, which may well use the same scale horizontally and vertically, and show the true slopes). Physical models allow visualization, from examining the model, of information about the thing the model represents. A model can be a physical object such as an architectural model of a building. Uses of an architectural model include visualization of internal relationships within the structure or external relationships of the structure to the environment. Other uses of models in this sense are as toys. Instrumented physical models are the most effective way of investigating fluid flows such as around hydraulic structures. These models are scaled in terms of both geometry and important forces, for example using Froude number or Reynolds number scaling. A physical model of something large is usually smaller, and of something very small is larger. A physical model of something that can move, like a vehicle or machine, may be completely static, or have parts that can be moved manually, or be powered. A physical model may show inner parts that are normally not visible. The purpose of a physical model on a smaller scale may be to have a better overview, for testing purposes, as hobby or toy. The purpose of a physical model on a larger scale may be to see the structure of things that are normally too small to see properly or to see at all, for example a model of an insect or of a molecule. A physical model of an animal shows the animals physical composition without it walking or flying away, and without danger, and if the real animal is not available. A soft model of an animal is popular among children and some adults as cuddly toy. A model of a person may e.g. be a doll, a statue, and in fiction a robotic humanoid, e.g. the mechas in the movie A.I. A model is a 3D alternative for a 2D representation such as a drawing or photograph, or in the case of a globe, a 3D, undistorted alternative for a flat world map.

2. The Solar System

The Solar System consists of the Sun and those celestial objects bound to it by gravity: the eight planets, their 166 known moons, five dwarf planets, and billions of small bodies. The small bodies include asteroids, icy Kuiper belt objects, comets, meteoroids, and interplanetary dust. The charted regions of the Solar System comprise the Sun, four terrestrial inner planets, the asteroid belt, four gas giant outer planets, and finally the Kuiper belt and the scattered disc. The hypothetical Oort cloud may also exist at a distance roughly a thousand times beyond these regions. The solar wind, a flow of plasma from the Sun, permeates the Solar System, creating a bubble in the interstellar medium known as the heliosphere, which extends out to the middle of the scattered disc.

3. Model Organism

A model organism is a species that is extensively studied to understand particular biological phenomena, with the expectation that discoveries made in the organism model will provide insight into the workings of other organisms. In particular, model organisms are widely used to explore potential causes and treatments for human disease when human experimentation would be unfeasible or unethical. This strategy is made possible by the common descent of all living organisms, and the conservation of metabolic and developmental pathways and genetic material over the course of evolution. Studying model organisms can be informative, but care must be taken when generalizing from one organism to another.

Topic Objective:

At the end of this topic student would be able to:

- Learn about the Robustness
- Understand the Mutational Robustness

Definition/Overview:

Robustness: Robustness is the quality of being able to withstand stresses, pressures, or changes in procedure or circumstance. A system, organism or design may be said to be "robust" if it is capable of coping well with variations (sometimes unpredictable variations) in its operating environment with minimal damage, alteration or loss of functionality.

Mutational Robustness: Mutational robustness describes the extent to which an organism's phenotype remains constant in spite of mutation.

Key Points:

1. Mutational Robustness

Mutational robustness describes the extent to which an organism's phenotype remains constant in spite of mutation. Selection can directly induce the evolution of mutational robustness only when mutation rates are high and population sizes are large. However, there may be considerable indirect selection for mutational robustness and a correlated response to selection for robustness against non-genetic changes (i.e. changes in the environment). The conditions under which selection could act to directly increase mutational robustness are extremely restrictive, and for this reason, such selection is thought to be limited to only a few viruses and other microbes having large population sizes. Mutational robustness is thought to be one driver for theoretical viral quasispecies formation.

2. Mutations

In biology, mutations are changes to the nucleotide sequence of the genetic material of an organism. Mutations can be caused by copying errors in the genetic material during cell division, by exposure to ultraviolet or ionizing radiation, chemical mutagens, or viruses, or can be induced by the organism, itself, by cellular processes such as hypermutation. In multicellular organisms with dedicated reproductive cells, mutations can be subdivided into germ line mutations, which can be passed on to descendants through the reproductive cells, and somatic mutations, which involve cells outside the dedicated reproductive group and which are not usually transmitted to descendants. If the organism can reproduce asexually through mechanisms such as cuttings or budding the distinction can become blurred. For example, plants can sometimes transmit somatic mutations to their descendants asexually or sexually where flower buds develop in somatically mutated parts of plants. A new mutation that was not inherited from either parent is called a de novo mutation. The source of the mutation is unrelated to the consequence, although the consequences are related to which cells are affected. Mutations create variation within the gene pool. Less favorable (or deleterious) mutations can be reduced in frequency in the gene pool by natural selection, while more favorable (beneficial or advantageous) mutations may accumulate and result in adaptive evolutionary changes. For example, a butterfly may produce offspring with new mutations. The majority of these mutations will have no effect; but one might change the color of one of the butterfly's offspring, making it harder (or easier) for predators to see. If this color change is advantageous, the chance of this butterfly surviving and producing its own offspring are a little better, and over time the number of butterflies with this mutation may form a larger percentage of the population.

Neutral mutations are defined as mutations whose effects do not influence the fitness of an individual. These can accumulate over time due to genetic drift. It is believed that the overwhelming majority of mutations have no significant effect on an organism's fitness. Also, DNA repair mechanisms are able to mend most changes before they become permanent mutations, and many organisms have mechanisms for eliminating otherwise permanently mutated somatic cells. Mutation is generally accepted by the scientific community as the mechanism upon which natural selection acts, providing the advantageous new traits that survive and multiply in offspring or disadvantageous traits that die out with weaker organisms.