Unit VI CAD Customization & Automation [08 Hrs]

Introduction, Limitations of 2D drawings, Introduction to Product and Manufacturing Information (PMI), Model Based Definitions (MBD), Applications of PMI & MBD.

CAD Customization: Introduction, advantages and disadvantages, Applications of Customization Interfaces, Product Customization Approaches - Part Modeling Customization, Assembly Modeling Customization, Drawing sheets & PMI Customization, CAD Automation Introduction to Application Programming Interface (API), Structures of APIs, Coding/Scripting for customization, Introduction to CAD API Development, CAD Files &application handling.

In engineering scenarios, one may encounter complex design situations. Previously, designs were drawn on sheets and manufactured manually using old school techniques. But now, things have changed with the introduction of CAD customization and design automation.

- CAD customization is the development of support tools and technology which drives CAD automation of repetitive tasks in the design process.
- Design automation is knowledge based engineering approach which logically combines various engineering concepts with real time application study during product development.

The use of CAD software allows designers to introduce more details and save a considerable amount of time.

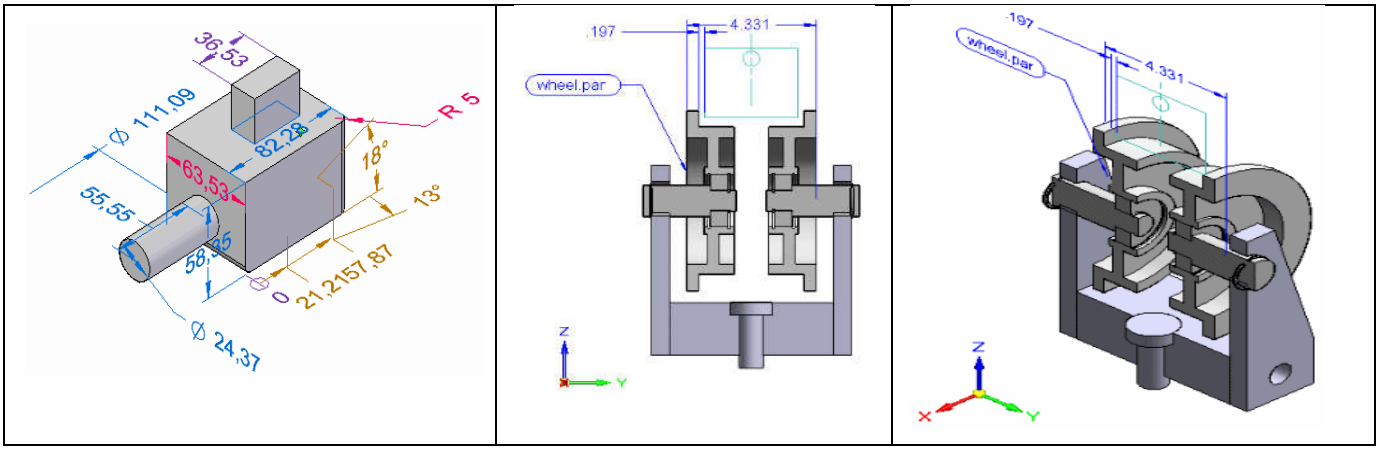
When CAD customization and design automation are integrated in engineering application, a number of advantages are obtained. With CAD customization, the production of a drawing and design of a mechanical component can be generated with great precision. This allows engineers to make quick modifications to any problems observed in the design. In other words, the design can be customized in accordance with the needs outlined before or after the CAD design is generated. Moreover, mechanical customization and manufacturing automation go hand in hand in reference to CAD software application.

Limitations of 2D drawings:

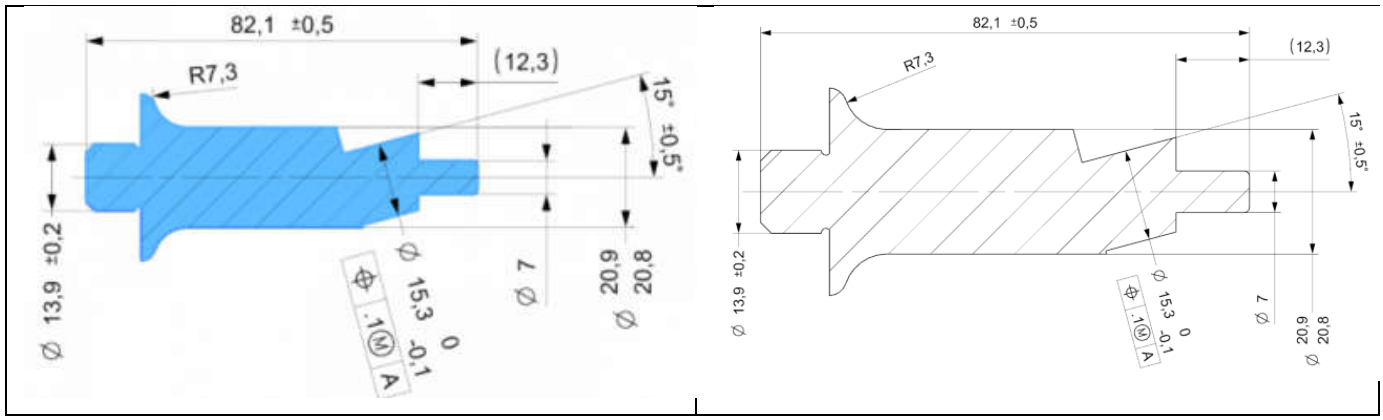
1. Complicates Checking Processes*:* 2D drawings aren't able to capture the complexities of product design. They don't take into account assembly and fit. Products that are created from a 2D sketch require a lot of work, as there are bound to be more errors. If products are created by numerous people, the checking process gets even more colluded. The drawings are forced to go back and forth over and over until finally, after laborious hours, the process is done.
2. 2D Design Requires Prototypes*:* 3D models communicate a lot of information regarding fit and potential issues. Because 2D drawings can't adequately display that information, they are forced into physical prototyping. In the case of a 2D drawing, the only way you can spot problems is to create the prototype, tear it down, and rebuild. This prolongs the product development cycle dramatically as you're forced to include reworks and re-engineering of prototypes.
3. Design Changes are Difficult*:* Making changes in designs is a time-consuming process, and it's even more tedious for 2D designs. Designs may need to be recreated numerous times in different views to capture all the details of a single part.

Introduction to Product and Manufacturing Information (PMI):

- **Product and manufacturing information**, also abbreviated **PMI**, conveys non-geometric attributes in 3D computer-aided design (CAD) and Collaborative Product Development systems necessary for manufacturing product components and assemblies. PMI may include geometric dimensions and tolerances, 3D annotation (text) and dimensions, surface finish, and material specifications. PMI is used in conjunction with the 3D model within model-based definition to allow for the elimination of 2D drawings for data set utilization.
- Product Manufacturing Information, or PMI, consists of dimensions and annotations that are added to the 3D model and can be used in the review, manufacturing, and inspection processes.
- In synchronous and ordered modeling, PMI dimensions also provide an important design modification tool. By editing dimension values you can make changes to the model. You can lock and unlock dimensions to control how connected model faces respond to dimension value edits. And you can control the direction in which dimension edits are applied. This greatly simplifies the process of design, testing, and update.
- Product and Manufacturing Information conveys non-geometric attributes in 3D computer-aided design (CAD) systems necessary for manufacturing product components and assemblies. PMI may include geometric dimensions and tolerances, 3D annotation (text) and dimensions, surface finish, and material specifications. PMI is used in conjunction with the 3D model within model-based definition to allow for the elimination of 2D drawings for data set utilization. Names of PMI Annotations: Text PMI, Roughness PMI, Datum PMI, GD&T PMI, Dimension PMI and Flag Note PMI.
- PMI can be used to generate annotation on a traditional 2D drawing the data. However, generally, PMI is used to visualize product definition within the 3D model, thus removing the need for drawings. Some 3D model formats enable computer-aided manufacturing software to access PMI directly for CNC programming. The PMI also may be used by tolerance analysis and coordinate-measuring machine (CMM) software applications if the modeling application permits.
- Product and Manufacturing Information (PMI) consists of non-geometric data that is attached directly to a 3D CAD model to define geometric dimensioning and tolerance (GD&T), engineering and manufacturing specifications, dimensions, and text. PMI is part of Model Based Definition (MBD) and together these two elements are a part of a Digital Twin.
- Applying PMI to a 3D model can reduce or eliminate the use of 2D drawings and can be used downstream to perform tolerance analytics and coordinate-measuring machine (CMM) inspection.
- PMI is a command within NX that gives you the ability to create/attach dimensions and annotations to define the 3D model, and requires model views similar to the views on a drawing. These dimensions and annotations are associative to the 3D geometry, and if it is decided that a 2D drawing is required, then the PMI can be inherited from the 3D model and automatically applied to the drawing views.



- The image below demonstrates what PMI looks like in a 3D model view, and the next image down demonstrates the inherited PMI in a 2D drawing view:



Advantages:

- Reduces cost by ensuring that design intent is completely captured and associated to the model. Deducing and interpreting design intent from 2D information is no longer necessary.
- Reduces rework associated with inaccurate or incomplete manufacturing information.
- Reduces manufacturing errors encountered as a result of manual translations and enforces “characteristic accountability” for the final product definition.
- Increases productivity and quality by documenting the information once and reusing it everywhere (redundant data is no longer required for downstream applications).
- Supports concurrent engineering by facilitating the documentation of models earlier in the design process. Design collaboration teams no longer need to wait for the production of the drawing to communicate design requirements.

Applications:

- Analysis of the production department
- Analysis of the quality department
- Analysis of the research and development department
- Analysis of the sales department
- NC-Simulation to create sequence of manufacturing.

- Finite element analysis, PMI helps the user to take the information he needs for the modification of the product used for the simulation.
- Tolerance analysis, it helps the user of this analysis to have directly the PMIs information in 3D models in early phases.

Model Based Definitions (MBD):

- **Model-based definition** (**MBD**), sometimes called **digital product definition** (**DPD**), is the practice of using 3D models (such as solid models, 3D PMI and associated metadata) within 3D CAD software to define (provide specifications for) individual components and product assemblies. The types of information included are geometric dimensioning and tolerance (GD&T), component level materials, assembly level bills of materials, engineering configurations, design intent, etc. By contrast, other methodologies have historically required accompanying use of 2D engineering drawings to provide such details.
- Modern 3D CAD applications allow for the insertion of engineering information such as dimensions, GD&T, notes and other product details within the 3D digital data set for components and assemblies. MBD uses such capabilities to establish the 3D digital data set as the source of these specifications and design authority for the product. The 3D digital data set may contain enough information to manufacture and inspect product without the need for engineering drawings. Engineering drawings have traditionally contained such information. In many instances, use of some information from 3D digital data set (e.g., the solid model) allows for rapid prototyping of product via various processes, such as 3D printing. A manufacturer may be able to feed 3D digital data directly to manufacturing devices such as CNC machines to manufacture the final product

Traditional Approach	**Model based Approach**
• 3D model with 2D drawing containing GD&T / PMI. • Human-readable • Reliance on personnel & interpretation. • Labor intensive, especially revisions & rework. • Multiple, propriety data formats. • Not mapped to a "single source of truth."	• 3D model with embedded GD&T / PMI. • Human-readable and machine-readable. • Reliance on process & data. • Reduction of labor time because of upfront encoded knowledge. • Universally accessible data. • Data mapped to design model.

- **Advantages:**
    1) Man hours saved: up to 80% total process hours saved compared to drawing-centric approach.
    2) Frees up engineering time for improving design and products.
    3) From skilled worker to smart worker: working on data & generating insights.
    4) Digital links between design and makers.
    5) Next generation of engineers see and design in 3D.
    6) Reduces human error through typing or interpretation
    7) Machine-readable 3D CAD & PMI for automation.

8) Removes the “middle man” or engineering drawings.
9) More feature-rich data for better instructions for the end user.
10) More iteration and process breakthrough improvement.
11) Higher quality inspections with measurement optimization algorithms
12) Transparency and interoperability along the whole process
13) Better products, better pricing, better margins.
14) Shorter product development cycles, faster time to market.
15) Staying competitive, first-mover advantage

- **Disadvantages**

1) *MBD is Disruptive:* Doing MBD is completely different from 2D drawings requiring design engineers to do more upfront work for a bigger impact downstream which they don't get to see. It also requires manufacturing engineers and suppliers to have the capability to receive MBD data and validate their models against the authority model in case there's a difference in CAD software. So it does require learning new or adjacent skills, processes, and tools to get MBD started.
2) *Resistance & Lack of Skill:* Manufacturing processes is about repeatability and stability. In short, if it ain't broke, dont' fix it. Change is hard and resistance to it is natural and encouraged. Engineers do have to learn new skills and new ways to complement the MBD process. Until there's a clear directive or event in the horizon, learning new things to get the "same" results isn't worth the effort.
3) *Lack of Maturity & Strategy:* In general, MBD is still in the early adoption phase while needing a few more years to reach early majority. The innovators of MBD, especially the ones who have succeeded, aren't publicly sharing their results to protect their "secret sauce" and maintain a competitive edge. This leads to a lack of definitive & concrete information, misconceptions of MBD, slower adoption, which effects the advancement of MBD software tools. Therefore, MBD will continue to move slowly forward until companies find out what their top competitors are doing.
4) *Another roadblock is a lack of management buy-in:* Current and immediate MBD ROI is focused on time-savings and faster processes, but lacks the value-add punch that most senior-level executives and decision makers need to change business process. MBD does produce the bottom line impact, but meaningful double-digital ROI can take up 5 to 10 years depending on the size of the company and speed to execution from case study to pilot project to company-wide implementation.

CAD Customization:

Introduction:

- Manufacturing industry has been using CAD software for sometimes now. These are the times when engineering departments, R&D centre & Design departments use Computer-Aided design (CAD) to ease up the product development process, thereby reducing the entire cycle time. CAD software makes our working fast, efficient & accurate.
- While CAD software comes with its own offering of general tools, it is a bit hard to fathom what each individual user may find useful to accomplish very specific tasks. Such limitations have pushed the minds of developers of the CAD systems to come up with the capability of customizing their software to cater to

the needs. With customization, it is possible to modify or create new tools that are better suited to our needs. One of the great improvements we can get with customization is to replace a series of commands with a single tool that accomplishes the task.

- CAD customization is the activity of creating specific enhancements or tools to support CAD software. As name suggests, *CAD customization means customizing or configuring OOTB (out of the box) CAD software to suit the specific needs of a particular organization.* CAD customization predominantly involves developing supporting tools for CAD software.
- It is mostly customized which means it is suited to a clients particular requirements. CAD software built en-masse might not satisfy the needs of every requirement, as many organizations have their own specific criteria. That is when customizing CAD software comes into play. Customizing existing CAD software is perhaps the fastest and most economic way of getting the work done.
- CAD customization is the development of support tools and technology which drives CAD automation of repetitive tasks in the design process.
- Design automation is knowledge based engineering approach which logically combines various engineering concepts with real time application study during product development.
- Customization of CAD software helps customers to do things faster, efficient and accurate. Most leading CAD software like CATIA, Solid Edge, Solid Works, AutoCAD, Inventor, etc. allow users to customize using their respective API package. CAD customization can be a small macro to a complete workbench inside the software. Organizations incline towards customization either for KBE, design automation, process automation or integration with other tools.
- Process Automation need in the industry is similar to that of Design Automation. With Process Automation Engineers can focus on the high level design. By allowing the customization for process automation to take care of small things. The small things can range from adding a revision automatically in drawing table to automating certain business logic.

Need for CAD Customization

- **Implementing a functionality that does not exist in the OOTB package:** The activity of CAD customization is carried out when a particular organization needs tailor made CAD software to address their need. It might be a separate functionality that a specific task needs or it might be about a format.
- **Repetitive tasks can be done in a single click:** Working on a product using CAD software can involves repetitive actions. This often ends up consuming a lot of time. Although, most CAD software provides generic features, one can have it customized for specific functions that repeat more like a loop.
- **Checklist for inspection can be customized:** You can reinvent the way you conduct by creating smart inspection templates. This aids in streamlining the quality and documentation processes even more.
- **Wizards can be created for guiding the use through the complete workflow:** Wizards are used to properly set something up. In some cases, wizards are used for setting up all tool-path and drilling operations within the CAD-CAM system. CAD customization can setup automated wizards for carrying out repetitive tasks and regression testing without having to put in extra emphasis and time on those, thus completing a workflow without human intervention.

- **Big time saving impact:** Companies have the capability to automate design, process, and systems integration when customizing CAD software. With customization of CAD functions, companies automate redundant tasks and experience great time savings.
- **Core focus on product development:** CAD customization allows engineers to keep their prime focus on product development without having to worry about support functions.
- **CAD Customization effect on digital thread:** CAD customization and automation of CAD software propels advancement in areas such as the digital thread.

Steps for Creating a Customization

Before developing customized CAD software, make some preparations as follows:

- Try your hands on a few simple drawings; follow a tutorial to see how the commands work.
- Understand the kind of work the user does, identify the issues he is facing, ask for features the user would like to have.
- Examine the available customization tools and find the most effective way to get the job done.
- A deep understanding of the function library is an absolutely necessary condition for customization.
- Use Software Engineering methods to plan the development of the customized system.

Mechanism of CAD Customization

Most CAD systems provide the following two mechanisms

- Record-Edit-Play of a macro or VB code

  VBA stands for Visual Basic Applications, which is an event driven programming language by Microsoft. It also allows integration with other applications that use VBA. The implementation of VBA in CAD customization is easy to learn and use. Developers can create application prototypes and receive feedback on designs quickly. VBA provides an extremely efficient way for manipulating CAD objects and exchanging data with other applications.
- Develop an Add-On using Open APIs or toolkits

  Another method for customizing CAD software is by developing add-ons using open source API's and toolkits. One can develop API implementations by using a developer toolkit. Nowadays, many API's come as open source which makes the whole operation a lot smoother. API's can be fabricated as per the requirements and can be applied as an added feature. One important factor is that, the API must be compatible with the said CAD software.

Advantages of CAD Customization

Customization of CAD software has indeed introduced us to many benefits which are as follows:

- Access to a functionality that does not exist in the OOTB package
- Improving the efficiency of the team by providing tools for faster development
- Reducing the manual error in performing many tasks
- Reducing the skill requirement of the operator (A wizard for a process can allow a user with relatively less experience to complete the tasks)
- Capture and protect the proprietary domain knowledge in a custom command/wizard
- By applying time saving automation, it increases productivity

- Reduces workload by huge proportions eliminating tedious tasks, data entries, and numerous repetitive steps.
- The usage of custom made algorithms helps in reducing errors
- Customization is a great mean to integrate a software with latest technologies

Four major problems that often arise while developing a customized CAD application.

1) **Capturing Design Data to be Programmed**

   During our initial discussion with the design team to understand the design process, it's very difficult for the engineers to explain the process of design engineering clearly, so that it can be brought under the framework of a system. This lack of standardized processes for product design makes it complex to understand the areas that can be automated.

2) **Improper Task Identification**

   It's very important to identify the right tasks or parts of the process to be automated. Selection of wrong tasks or not so useful tasks for automation defeats the entire purpose of design automation. Moreover, proper planning of development is key to successful completion of the project.

3) **Application System Design**

   While developing the system for a CAD customization application, a common problem is to find a situation where the design rules and facts are not interlinked. This makes system designing of the application not so module based. In today's highly developed system framework design world, not having a 100% module-based system appears as poor design.

4) **Data Formatting**

   Design automation applications are driven by input and output data, all the data includes the description of geometry. This system has to convert the CAD data that's provided as input to geometry-based data for computing further. As the companies moved to CAD systems, these systems have to be developed to perform the task as expected.

Challenges with CAD customization

Like every other entity out there, CAD customization comes with its own drawback. One big challenge with CAD customization is keeping it in sync with the latest technology in the market. Also, every CAD software is gets its new releases so it becomes quite hectic to keep a check and customizing accordingly. We have learned before how add-ons/plug-ins has been introduced to add new features to CAD software. Such add-ons are also prone to updates which need to be worked upon to make it compatible with customized software. Modern technology, however, is working its way towards making the process of upAutoLISP, VisualLISP & DCL dating and customizing a more lenient process.

CAD Software	Customization interface
AutoCAD	AutoLISP, VisualLISP & DCL
SolidWorks	SolidWorks API, Macro files
SolidEdge	SolidEdge API SolidEdge VBA
Pro/ENGINEER	Pro/TOOLKIT J-Link
Autodesk Inventor	Inventor API Inventor VBA

Benefits of CAD Customization in Design, Process, and Systems

Companies have the ability to automate design, process, and systems integration when customizing CAD software. For instance, many of the repetitive tasks can be computerized within CAD software. With customization of CAD functions, companies automate redundant tasks and experience great time savings. CAD customization allows engineers to keep their core focus on product development without having to worry about support functions. The benefits of CAD customization include enhanced productivity, reduced human errors, and systems integration. In addition, customization and automation of CAD software enriches advancement in areas such as **the digital thread**.

CAD Automation applications are developed using API programming as add-ons over commercially available CAD platforms (like CATIA, Inventor, SolidWorks, SolidEdge, etc). Mundane tasks that require rule-based decision making are considered as ideal for automation. These custom applications intelligently extract data, apply rules, make decisions and perform operations automatically thus improving the quality and reducing cost.

Design Automation – This involves identifying repetitive design events and tasks that require multiple mouse clicks and automate them. This lets engineers focus on high-level design, rather than the mechanics of the drawing technology.

Process Automation – This involves understanding of the design lifecycle and automating supporting steps based on certain rules. This helps in reducing human error and maintaining consistent behaviour while integrating with other applications.

Applications of CAD customization:

- Design process automation
- Drafting automation
- Macros development
- API and toolbar customization
- User interface creation
- Finite Element Meshes Generation
- Bathroom and Kitchen Layouts

Examples of process automation with CAD customization:

- Generate bill of materials of developed product with parts lists
- Print bulk sheet job without supervision
- Assign steps with computer or manual decision making
- Generate logs of all processes generated
- CAD models & drawing creation with minimal inputs
- Revise drawing tables

Product (Mass) Customization Approaches

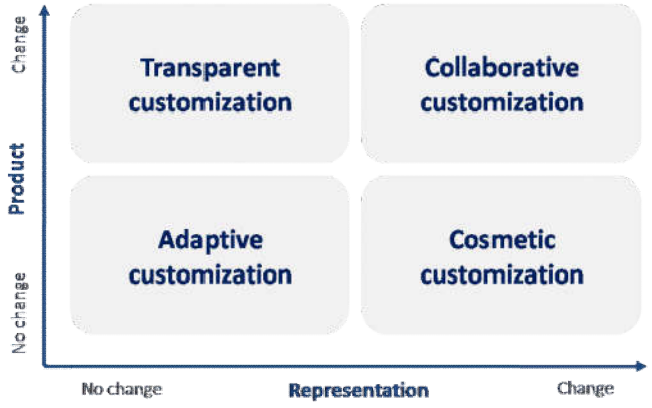
Mass customization can be defined as the ability of a company to deliver modified goods and products to fulfill the needs of individual customers. The customized products are provided at the same price as of the number of mass production products. Customers are provided with basic product and a range of features that they can add or subtract to get a unique product.

Mass customization is a concept where customers are provided unique custom-made products at the mass production prices. This concept of branding is becoming quite popular with the companies these days, and more and more companies are adopting this business concept to boost their sales. The concept of mass customization is becoming popular among people because of their desire to have unique things. For example, people want to have a wallet with their name carved on it.

The concept of mass customization first introduced in the market under the names of "made-to-order" or "built-to-order." According to this mass customization, products were designed for the customers only after they have placed an order. The products designed under "made to order" or "built to order" were little expensive than the products made through mass production. But the concept of "Mass customization" was introduced so that customers can design products in their style. They can choose from the range of feature provided by the seller and can have a unique product designed as per their taste.

One thing that makes mass customization different from made to order and built to order concept is that the price of products made through mass customization is similar to or near to the price of products made through mass production. The concept of mass production is not only used by the large organization, but small entrepreneurs widely use it. Entrepreneurs use a remarkable amount of creativity to design mass customization products. To do this, they pay more attention to their design phase and produce products to satisfy the unique needs of their customers. Moreover, mass customization brings more business to the entrepreneurs as every customer wants to be treated as special, and companies learn about the choices of their customers. They use this information about their customers to enhance their business ideas and produce products which will help them to serve their customers in the right manner. There are different types of mass customization that companies can opt to enhance their business. One popular type of mass customization is adaptive customization. In adaptive customization, the basic product is produced through mass production, and customized features are added once the order is placed.

There are fewer chances of loss in mass customization as the customer pays before they can ask for the customization to be made. There are many other types of mass customization other than adaptive customization.



1) **Cosmetic customization** – Product features are standard but product representation is tailored as per customer need. Cosmetic customization is a type of mass customization where standard products are sold in different ways to a different group of customers. With the increasing demand of customers for customized products, more and more companies are opting for cosmetic customization. Now the companies sell standard products but in different sizes, shapes, containers, or packaging so that the needs of customers can be fulfilled. Products produced through cosmetic customization usually carry the name of customers. For example, a recent trend of cosmetic customization is seen in the apparel industry, where people spend billions of dollars to buy customized clothing such as a t-shirt and sweatshirts, etc. One more example from the apparel industry is the introduction of the plus-sized clothing line. Earlier apparel companies used to sell clothes of small, medium or large sizes but nowadays, companies are selling clothes of various plus sizes and even get customized ready clothes as per the unique requirements of the customers. Even the impact of cosmetic customization is also seen in the retail industry. Retailers are opting the cosmetic customization method to provide customized product to their clients. For example, a baker not only sells cakes made through standard design and ingredients but have started selling cakes made as per the unique theme told by the client and they also use different ingredients to prepare customized cakes for customers with different health conditions. E.g. For example, you can highlight a specific attribute or benefit of your product on one packaging and highlight another attribute on another one. Many supermarket brand foods are exactly the same as the premium brands, even made by the same manufacturer.
2) **Transparent customization** – Product features are customized without customer's knowledge as representation doesn't change. The transparent customization is a quite new and unique type of mass customization. In transparent customization, companies customized ready products for customers by constantly analyzing their behavior. This method of mass customization is not very popular among the companies as it requires a lot of additional work and efforts to learn about the customers' buying behavior and their needs and choices. However, if implemented properly, this method can be a successful strategy to gain the loyalty of customers and boost sales incredibly by putting a few extra efforts. For example, by engraving customers names into the product bundling. But a more common use would be through product recommendations on your e-commerce store. The products recommendation tool on Shopify is an example of transparent customization which offers your customers products they might want based on things like recently viewed products.
3) **Adaptive Customization** – Customer is provided with the ability to change both the product's functionality and its representation to meet his or her particular needs. In adaptive customization, products are not built from scratch as per the guidelines provided by the customers. But the basic product is prepared through mass production, and customers are given choice of a variety of features that they can add to the basic product make it unique. This type of mass customization easy to make the part of the existing business style. Only small changes are required to be made in the production process to provide customized services to customers. As the base product is made through mass production, the cost of a customized product is not high, and people of all class can afford it. For example, an online company the messy corners sell wallet, purse, travel bags, passport cover, etc. They mass-produced these products in different color and design and provided a

range of options for tags, title, name, etc. to be carved on the products to make it customized. Customers can select the product that they want to buy and select the customized from the drop-down menu provided on the website to select different features that they want to be carved on the product at a small additional price. Adaptive customization is best to fit the mass customization business idea for online businesses. For example, TLM color changing foundation is a beauty product which automatically adjusts depending on the skin tone of the customer.

4) **Collaborative customization** – Product is tailored as per the customer's need and also the representation is modified as per the customer's comfort. This type of mass customization business idea is a little expensive for the customers. It is for those customers who want to create highly customized products. The meaning of collaborative customization is to create a customized product with the collaboration of clients. In this method, customizers talk with the client to understand their needs and then use the information obtained from the client to create a product that they desired. This type of mass customization is suitable for clients who are confused with the range of options and who don't exactly know how they want their product. The customizers help them by narrowing down their options and create a unique product for which fulfill their requirements. This type of mass customization is preferred by people who ant highly customized products and don't have a budget limit. E.g. choosing which toppings you want on your pizza, Helmade is a company that offers customers the options to design their motorcycle helmet in 3D.

Advantages of Mass Customization

1. Happy and satisfied customers.
2. Enhanced reputation of the company.
3. Increased revenue.
4. Your workforce gets to showcase their creativity.
5. Lower inventory and unsold goods.
6. less wastage of raw material
7. Less or zero chances of cancellation.
8. Fast and efficient production process.
9. Get to know your customer better.

Disadvantages of Mass Customization

1. Tiring process of figuring out what customer wants.
2. The constant process of thinking about creative and innovative ideas to please customers.
3. Keeping and maintaining stock of the variety of material.
4. Tiring process of convincing customers for the higher price charged.
5. Difficult to get the estimate for product demand.
6. Need for highly flexible production technology and machinery.
7. Expenses of maintaining direct customer relationship.

Part Modeling Customization:

- During the creation of 3D model user is impatient to do repetitive task and thousands of mouse clicking, also draftsman require large skill of modeling software. To avoid these problems and to speed up cycle

time from product design to manufacturing automation of part modeling CAD software is required. CAD software is required for the modeling the part, but instead CAD software can use parametric modeling concept.

- Object customization in Computer Aided Design (CAD) is a method used to modify the sketch parameters and change the model geometries. This method is one of important features in part modeling which empowered CAD user to simply modify their product. The conventional method of modifying CAD model is usually relied on the manual editing. E.g. use of Visual Basic (VB) programming with custom Graphical User Interface (GUI) generated in NX10 (CAD/CAM software) interface.
- Object customization in CAD can be carried out by using the parametric modeling technique. Basically, the geometry is mainly controlled by non-geometric features called parameters, which can be defined by dimensional, geometric or algebraic constraint. Parametric CAD enables user to do rapid alteration of existing models by simply editing the values of respective parameters. Modification of object will happen right after the user finish to set the parameter value. This technique comes in forms of graphical
- User interface (GUI) where the value of the parameter needs to be filled up by the user. GUI allows interaction between user and the computer to accomplish desired goals. The object can be modified but it requires user to know the parameters value and run the program before the modification tool place in the model interface. The drawback of this technique is the modification towards object only happened after user finish to set the parameter value which makes this modification process is not in real time.
- E.g. the customer would require furniture that can fit perfectly with the available space. Hence, designer needs to deal with a lot of modifications in term of size, additional compartments and shapes. To execute these tasks manually will be time consuming as it requires several repeated cycles before the final design is achieved. In order to resolve this issue, the modification instructions used in CAD can be translated into programming language which leads to the automation in modifying the model. The codes generated can be exploited and modified, then link with the custom GUI to allow real time object customization in the modeling stage. Providing a freedom to customers to control certain design parameters will boost their excitement and feeling in purchasing the product.
- A new technique has proposed to generate CAD models automatically. There are two methods formulated, one is by writing a complete program manually / modifying GUI and another one is the utilization of macro tool in the modeling software. The aim of this development is to shift from manual modeling technique to automation modeling process.
- Helpful way because of the changing market condition and customized requirements from customer. The product can be customized as per the requirement of customer in various ways depending upon suitability of the design application (software) being used. T his customization also helps in reduction of product design cycle time and also redesign time based on manufacturing requirements in some cases. Customization allows product designer to design products by defining parametric relationship and then use of parametric modeling.

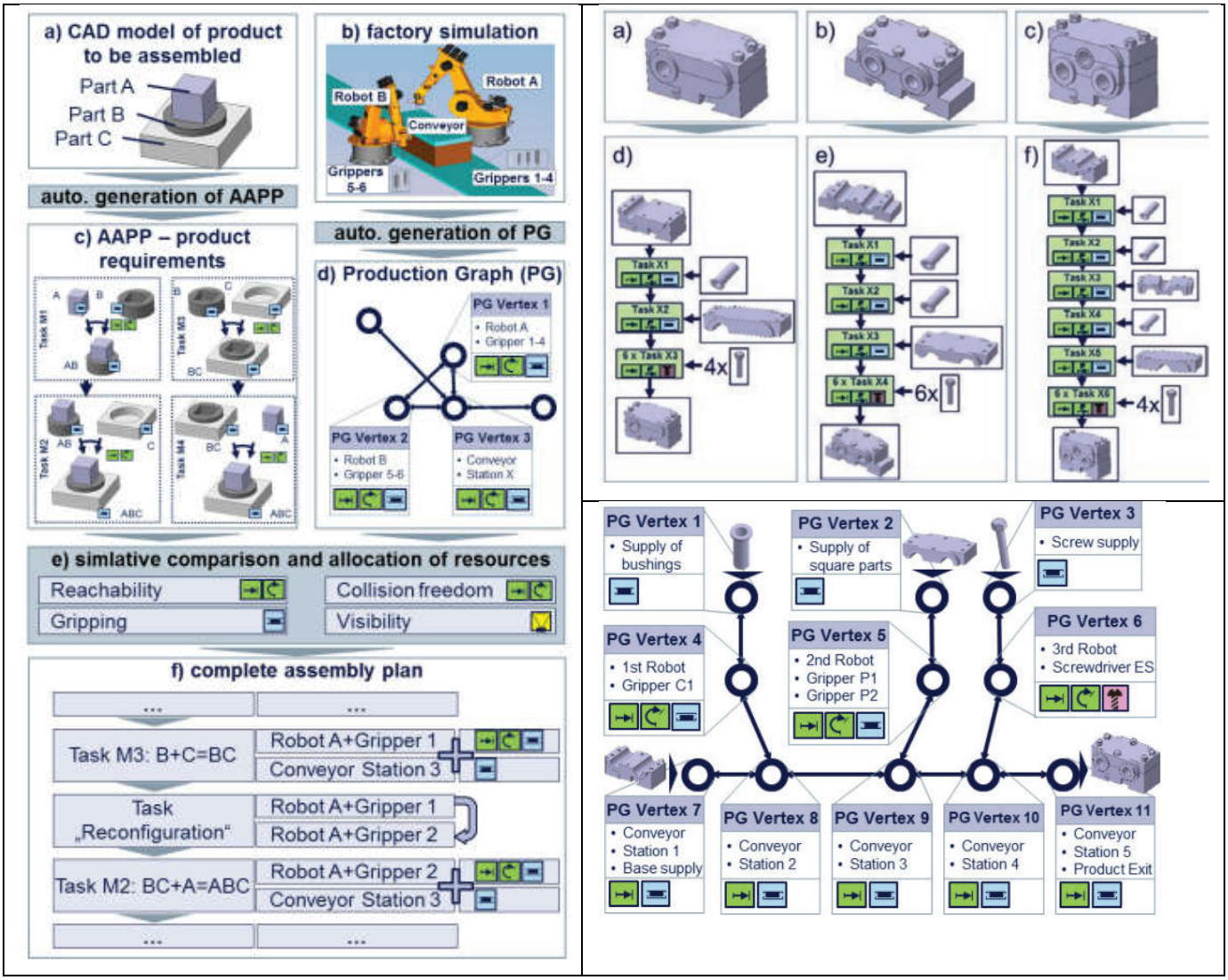
Assembly Modeling Customization:

The introduction of a new product variant or the integration of a new resource to the production system requires high manual effort and is time consuming. Mass customization and creation of variants is usually achieved during product assembly. Increasing modularization and compatibility of product components enlarges the product range and facilitates the introduction of new product variants and new components. Assembly planning and the selection of the optimal resource configuration however become increasingly complex and time consuming.

Automated assembly systems are usually used for specific predefined tasks. Only a narrow spectrum of the functional range of resources is utilized (e.g. the workspace of a robot in comparison to a repetitive motion or the restriction of a gripper to one gripping point of one specific part) due to manual efforts for planning and validation of the required processes. Furthermore the control code for the entire production system needs to be developed, tested and implemented manually.

The point to be considered is,

1) Tasks and Functional Primitives: allowing a solution independent representation of requirements and abilities.
2) Modeling of the product requirements: the product requirements as well as feasible assembly orders are modeled as a directed graph called the Augmented Assembly Priority Plan (AAPP). The AAPP consists of vertices, representing Tasks, and edges, modeling feasible assembly orders.
3) Automated allocation of resources: For the two initial subassemblies in each Task pairs of adjacent vertices in the PG are searched, assigned and added to the Task description in the factory specific AAPP, following the assumption that both subassemblies must be held by individual resources whose workspaces overlap. This allows the feasibility test of all value adding processes as well as the detection of missing or insufficient abilities.
4) Pre-Sequencing – Generation of rough assembly order: users can manually enter which parts or part families shall be incrementally moved first or last, automatically putting these parts in the first or last row of the matrix.
5) Assembly by disassembly: A part is moved until it reaches a predefined distance to the remaining subassembly. The movement direction is determined by geometrical constrains between the parts, the main mounting direction as well as the coordinate systems of the individual parts. In order to further increase efficiency, connecting elements like bolts or screws are moved primarily.
6) Input of part interfaces: the position of interfaces of each part as well as interface requirements must be entered manually by the user.
7) From assembly sequences to product requirements (AAPP generation): The complete AAPP is generated by modeling the assembly of each consecutive part as a Task which contains the sequence of earlier parameterized flow processes.
8) Use of Production Graph for better CAD-analysis results In order to further optimize the automated generation of the AAPP, the Production Graph can be utilized.



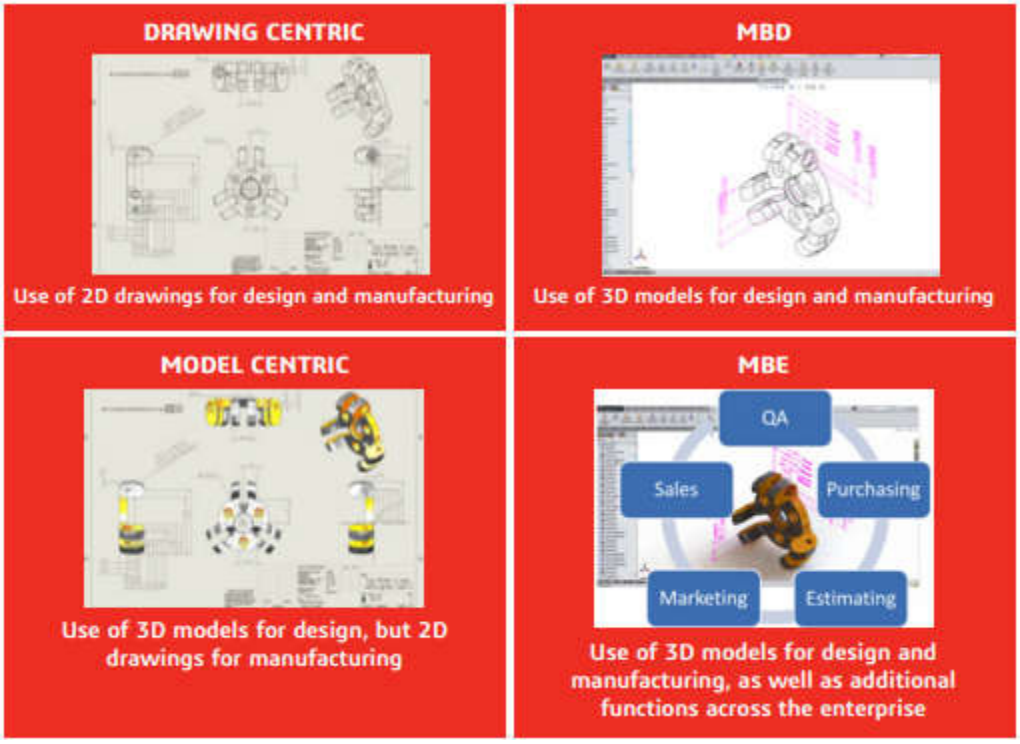
Advantages:

1) The system allows automated validation and planning of assembly processes with unprecedented flexibility and ease.
2) Familiar user interfaces promises easy integration and high usability.
3) The feasibility of an assembly with the available resources is validated, the optimal assembly sequence chosen and allocated to the available resources automatically.
4) The system takes different flexibilities of the production system into account, increasing the useful life and utilization of the available resources.

Drawing sheets & PMI Customization:

- MBD drawingless manufacturing solutions extend the benefits of 3D design to manufacturing, including time and cost savings—through improved, more tightly integrated communication of Product and Manufacturing Information (PMI) for production—as well as reduced scrap/rework, improved accuracy, and faster throughput.
- PMI is a way to add geometric dimensioning and tolerance (GD&T) symbols to 3D models. By annotating models in this way, you improve productivity, ensure the 3D information is accurate, and reduce reliance on 2D drawings during design reviews.

- Adding PMI to a 3D model also makes sense from a design perspective because critical dimensions and manufacturing information is captured as you design. Also you are add-ing this information to a single model, unlike orthographic drawings where dimensions need to be spread across several views to relay your design intent.
- 2D Drawing Generation Adds Time to Manufacturing Planning.
- Producing 2D Drawings is Costly.
- 2D Creates the Potential for Quality Issues.
- Emerging Industry Standards Require 3D.
- PMI Bringing Products to Market Faster.
- Reducing Production Costs.
- Improving Quality, Accelerating Engineering Change Orders.
- Complying with New Standards.



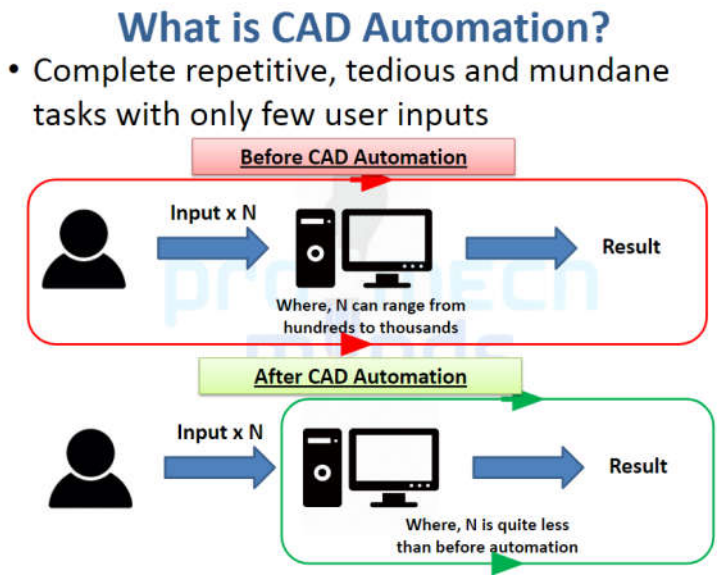
Using PMI in 2D

1) Drawings that include PMI can be created in both draft-quality and high-quality drawing views.
2) View orientation is defined by your saved model view (it's good practice to use meaningful names as you create them) along with visible components if you are working on an assembly file.
3) You can add more model views to your model if later you find another view, angle, or perspective is required.
4) You are able to continue annotating a drawing view as you would if you had not chosen to include PMI.
5) You can set Quick Sheet templates to further speed up drawing production.
6) If you add a prefix or tolerance to a PMI dimension in 3D, you will be notified on the drawing.

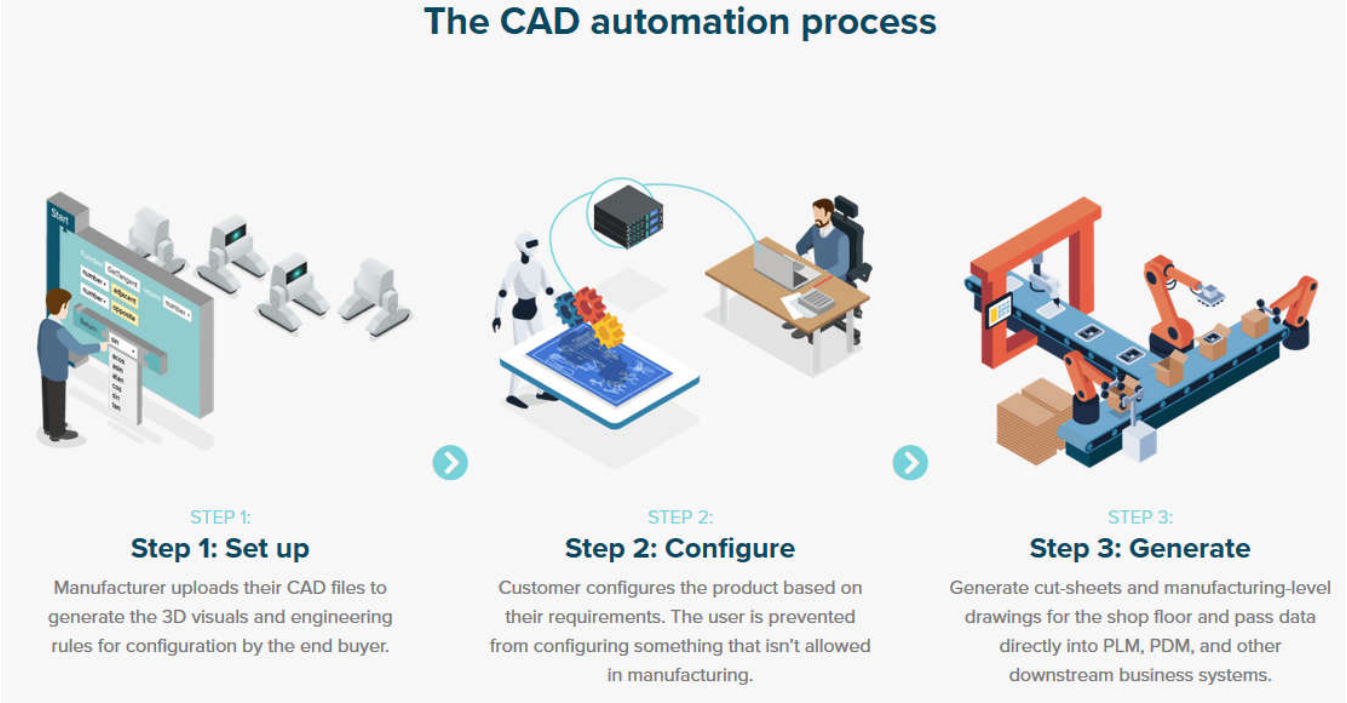
7) Dimensions are associative, so changing your model updates the 3D PMI dimension, which in return updates the drawing.
8) At the time of writing, PMI annotations such as callout labels and balloons are not displayed on the drawing.

CAD Automation

CAD automation enables users to automate translation and repair processes without having to open or view the files graphically. Many files can be processed automatically at one time, breaking through CAD data bottlenecks in engineering and design departments.



- **Automating CAD bridges customers, teams, and processes.**
- **Eliminate the bottlenecks for sales, engineering, and production teams.**
  Sell with certainty and confidence – and speed. With CAD automation, you can configure products along with your customers and produce validated drawings and pricing instantly.
- **Connect your sales to your shop floor.**
  More custom sales quotes with drawings in less time. With CAD automation, your sales teams won't have to wait for engineering to validate configurations or manually process drawings.
- **Save time and money.**
  CAD automation helps automate the quotation process, saving huge amounts of time for your sales teams and anyone contributing input to your quotes. This directly impacts sales costs and profit margins on each sale. Customers can see their design cycle times slashed from weeks to minutes.
- **Reduce errors.**
  Because design constraints are already defined and validated in our configuration, you can feel confident about the integrity of the design when it is generated automatically. Your Sales teams will be assured that a configured product is always able to be built to customer specification. User can generate a Manufacturing Bill of Materials (BOMs), a highly detailed parts list for your manufacturing team. The parts list can be passed into ERP systems, aiding inventory and invoicing processes.



Here are a few examples of CAD Automation.

Parametric Modeling: One of the things you have to understand is a product is made from the assembly of many parts and most of these parts are standard parts (as opposed to custom parts) and to be able to generate these standard parts instantly without having to actually model them saves a lot of time. This is called Parametric Modeling. In this you only have to enter a select number of dimensions of a part and you get an output model of the specified dimensions. The software generates the model directly based on the dimensions only.

For Example: Suppose you need a standard spur gear for your product. In the above image, you have to enter the required dimensions(The Parameters) i.e. Number of teeth, Module, Pitch circle diameter etc. and the required gear model will be automatically generated.

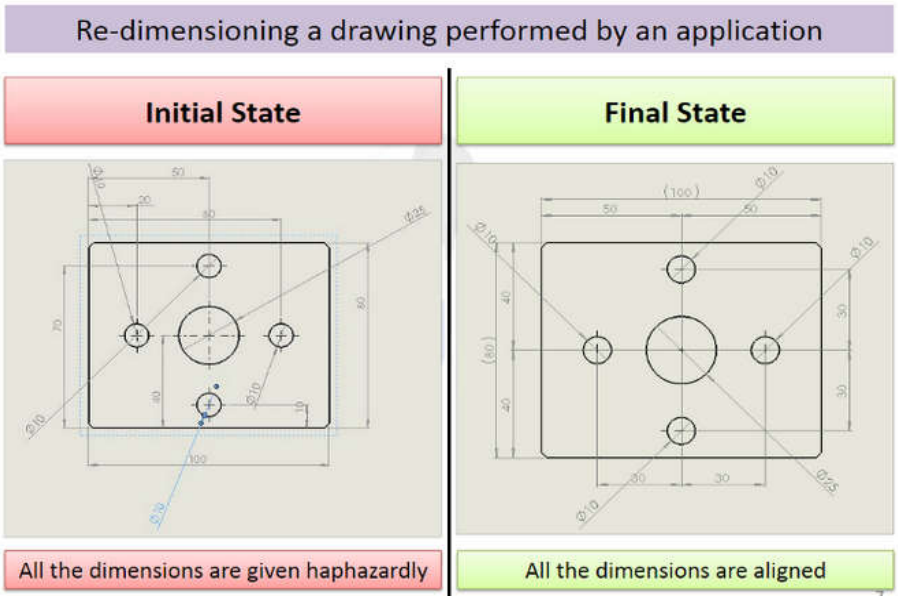
Custom CAD Tools: All companies have their own share of repetitive tasks. Each has its own requirements. If a tool can be created for that specific task in the software that is to be used then it reduces the job time from days to hours and even minutes. Now almost all CAD software has a certain degree of customizing ability in them. Using their APIs you can create tools to automate extremely specific tasks.

On Shape has built its own language called *Feature Script* which is designed specific for CAD users with no previous knowledge of programming. The actual features (Tools) in the Software are made using this script so you can copy the codes from the original tools and use it in your custom tool. The above mentioned Gear Tool is also a custom tool made using *Feature Script*.

Feature Recognition: Suppose you want to search for an available standard part based on a part you just modeled or for you assembly. Previously, you would have to go to a company website and search for the part based on serial numbers and part names. Now it is possible to input a 3D model of the part you modeled and get a list of recommended parts based on your 3D model. Of course this has not been implemented in all websites but this is a lot easier than the previous process. This is all possible due to *Feature Recognition.*

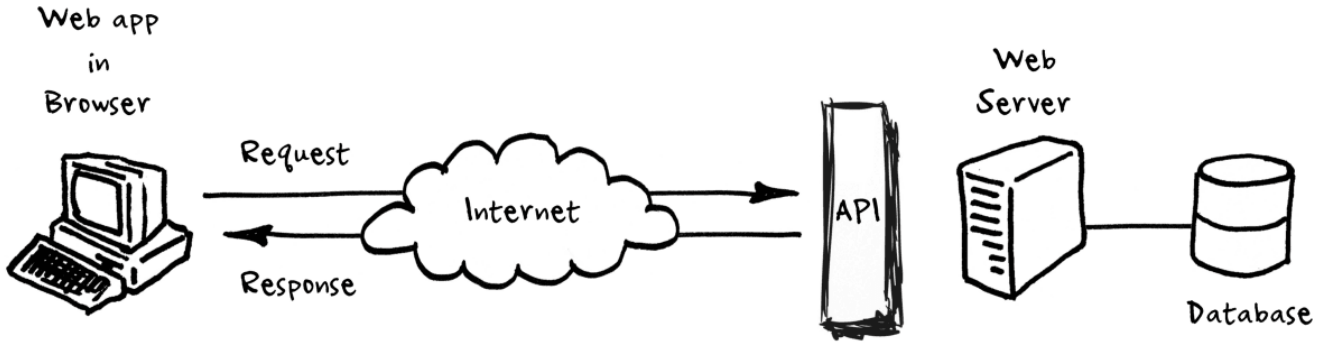
Feature Recognition in 3D CAD, is basically software's ability to distinguish shapes and tell what the 3D model is. It basically works by knowing this circular shaped thing is a "Cylinder". By combining basic shapes (cylinders,

cuboids, holes) software can be made to correctly classify parts to a given list of part types. E.g. a Bearing, Screw, plate, Shaft Another use for Feature Recognition is to evaluate, measure dimensions of a part. This is particularly useful when you have to model tens of thousands of parts and have to confirm (check) the dimensions of each. If a person takes 5 minutes to check the dimensions, the computer can do it within 3 seconds. Multiply that by 10000 and you can imagine why Automation saves time.



Introduction to Application Programming Interface (API):

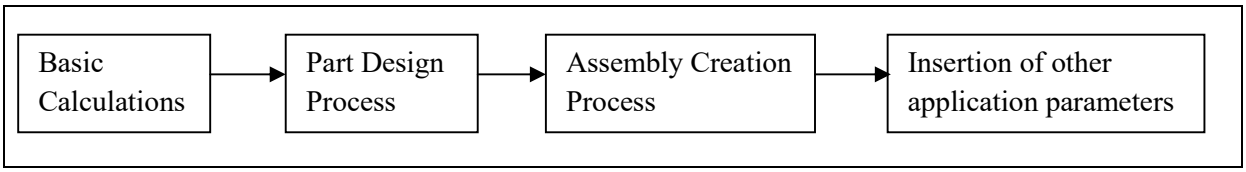
- The API is a platform for customization, and can significantly benefit your design process. It is very flexible, and can be used for a wide variety of tasks. Here are a few examples of potential applications:
  1) Automate repetitive tasks normally performed in the user interface.
  2) Create custom tasks.
  3) Create custom results quantities.
  4) Output results in customized or specialized formats.
- An Application Programming Interface (API) is a shared boundary provided by software to facilitate communication. In the case of a CAD system, it is a way to interact with the software and CAD files with another program.
- APIs in CAD programs open up new possibilities in how you interact with the program. From reading data to automating design, API's are a powerful asset.



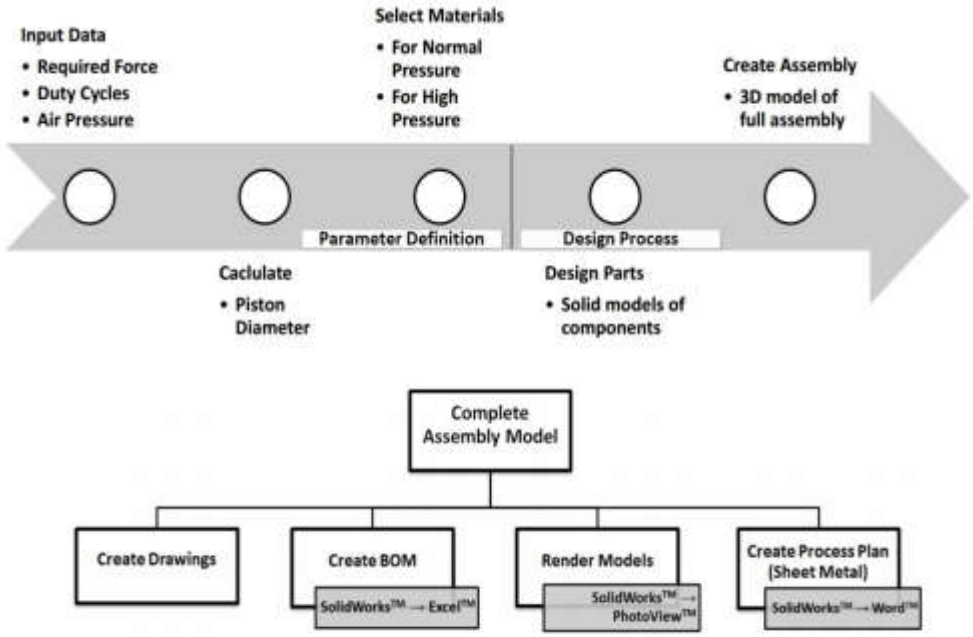
- There are three common ways to interact with the API.
    1) **Macro** – A small program or script to automate a common task, usually launched by loading the program with the macro utility. CAD software allows you to create macros by recording user actions as an easy jump off point. Useful for quick and small time saves. All macros are written in VB.Net, but no extra software is needed.
    2) **Add-in** – An application that exists within the CAD program, usually launched by a custom menu button. Useful for adding functionality that needs to fit seamlessly into the design workflow. Add-ins can be written in either C# or VB.Net, but either way you'll need your own development environment.
    3) **Stand Alone** – An external application that can launch and interact with CAD programs from another window. Usually launched like any other desktop application, with a shortcut. Useful for applications where data is gathered from CAD, but used for purposes other than design. Stand Alone applications can be written in either C# or VB.Net like an add-in.
- **Using API user can**
    1) **Create –** You can create new drawings, properties, features, and even files. Automating creation can save the overhead of setup, especially when setup protocols are well defined and consistent.
    2) **Delete –** With the power to create, comes the power to destroy. Useful for cleaning up a mess, most items that can be created can also be removed.
    3) **Update –** The downside of creating data is keeping it up to date. Out of date data is only slightly more useful than no data. Using the API to keep data up to date can save users from the purgatory that is data management.
    4) **Read –** Reading data is perhaps the simplest action with an API, but can be important. The data that is locked away inside a CAD model can be useful in the rest of the manufacturing process. Questions like: what is the BOM, which parts are purchased, which parts require paint, can all be answered manually, but compiling data quickly is what a computer does best.

Structures of APIs

With the use of the API of a general purposes CAD system it is possible to develop applications in short time that can be used to analyze various engineering situations. The main advantage of such applications is that there is no need of any physical model in order to simulate and analyze any engineering processes, or even to extract data. It is also clear that the programming of the API can speed up many standard CAD processes and save time that can be better allocated. The development of human to machine interfaces can also be achieved with the use of the API and can drastically increase the manufacturing productivity in today's modern industries.



E.g. API Structure for pneumatic double acting cylinder



Coding/Scripting for customization:

- CAD software is used to increase designer productivity, improve design quality and communications through documentation, and create databases for manufacturing. As the CAD modeling techniques become more and more advanced, it is necessary to complete product modeling and design changes faster than ever. Updating assemblies that have hundreds of sub-assemblies and parts manually in 3D modeling software is very complicated and time consuming. Undoubtedly, once a task is fully defined, computers and machines are unparalleled in executing it repeatedly with great speed and sustained accuracy.
- One of the easiest ways to automate a CAD process is to write a script. In computer programming terms, a script is a program that will run with no interaction from the user. In AutoCAD, a script file is an ASCII text file that contains a set of command line instructions to follow, just like an actor reading from a script. AutoCAD script files always have the file extension '.scr'. AutoLISP is the original and most popular programming language for AutoCAD. The reason for its popularity is that it is a natural extension of the program. No additional software needs to be run, and AutoLISP can run commands that Autodesk and other developers offer in the command window. The LISP code can be entered directly into the command window or loaded using '.lsp' or '.scr' files. Once a LISP program has been loaded, the built-in functions can be executed from the command window. These functions can be executed similarly to CAD commands, but it is the programmer who decides which messages to display. It is possible to use LISP code with a command macro that is activated from the CAD user interface or from a tool on a palette.
- Visual languages can be very useful for helping architecture students understand general programming concepts, but scripting languages are fundamental for implementing generative design systems. It is possible to learn to draw with AutoCAD and to program with AutoLISP for AutoCAD using the manuals and online aids offered by both Autodesk (knowledge.autodesk.com) and other independent developer websites (lee-mac.com, afralisp.net, or cadtutor.com). Self-learning through tutorials and videos is very

widespread and numerous websites are available to solve any questions we may raise using advanced search engines if we search for the terms 'AutoCAD' or 'AutoLisp' as appropriate.

- In the design of complex engineering products it is essential to handle cross-couplings and synergies between subsystems. An emerging technique that has the potential to considerably improve the design process is multidisciplinary design optimization (MDO). MDO requires a concurrent and parametric design framework. Powerful tools in the quest for such frameworks are DA and knowledge-based engineering. The required knowledge is captured and stored as rules and facts that will finally be activated upon demand. A crucial challenge is what kind of knowledge to store in order to create generic DA structures and how to store it.
- By using automation processes, it is possible to undertake designs without effort by the user; automation in the generation of designs not only saves time but also increases the quality of the results and reduces the possibility of human errors; multidisciplinary optimization of design reduces the learning effort and speeds up the acquisition of graphic skills.

Introduction to CAD API Development:

You can customize CAD applications by adding custom programs written in any of several programming languages that run within CAD software, including AutoLISP, C/C++, VB/VBA/VB.NET. CAD applications offers several API's : AutoLISP, DCL – Dialog Control Language, DIESEL, COM, VBA, ObjectARX, .NET

AutoLISP

AutoLISP is a interpretive programming language that you can use to call CAD commands, system variables, and dialog boxes. AutoLISP greatly extends the commands and functionality that are available in CAD applications. You can load and use Encrypted AutoLISP file in CAD applications

DCL, DIESEL, COM

DCL is an acronym for Dialog Control Language, a separate programming language that you can use with CAD application to create custom dialog boxes.

DIESEL is a rudimentary macro expansion. It is an acronym for Direct Interactively Evaluated String Expression Language. DIESEL is used in menu macros and toolbar macros. It also allows to customize the status bar. The DIESEL interpreter takes a string, processes it, and returns a string.

COM is a software architecture developed by Microsoft to build component-based applications. COM objects are discrete components, each with a unique identity, which expose interfaces that allow applications and other components to access their features.

.Net API

The .NET API enables you to manipulate CAD application and drawing files programmatically with the assemblies or libraries that are exposed. With these objects exposed, they can be accessed by many different programming languages and environments

Advantages to implementing a .NET API for CAD

Programmatic access to CAD drawings is opened up to more programming environments. Before the .NET API, developers were limited to ActiveX® Automation and languages that supported COM, AutoLISP®, and C++ with ObjectARX. Integrating with other Windows® based applications, such as Microsoft Excel and Word, is made

dramatically easier by using an application's native .NET API or exposed ActiveX/COM library. The .NET Framework is designed for both 32-bit and 64-bit operating systems. Visual Basic for Applications was only designed for 32-bit operating systems. Allows access to advanced programming interfaces with a lower learning curve than those for more traditional programming languages such as C++.

Object ARX

ObjectARX is the most powerful of the various CAD APIs, and the most difficult to master. The ObjectARX programming environment includes a number of dynamic link libraries (DLLs) that run in the same address space as CAD application. You can use DLLs to create new commands that operate exactly the same way as native AutoCAD commands.

Powerful Development APIs

Extensive APIs in various languages give members the power to create custom objects, complex applications and complete vertical solutions:

- Macro recording and replay
- LISP
- DCL – Dialog Control Language
- DIESEL – Direct Interpretively Evaluated String Expression Language
- COM
- VBA – Visual Basic for Applications
- ADS/SDS for C
- IRX – IntelliCAD Runtime Extension for C++
- TX – Teigha Xtension
- TA – Teigha Architecture
- TG – Teigha DGN
- TC – Teigha Civil
- .NET

CASE STUDY

- The Livermore Design Optimization (LiDO) code is used by designers and analysts to optimize designs. A classic example is to design the lightest structure that can withstand its loading environment. To do this, LiDO combines simulation, solver and optimization LLNL software libraries. In this way, it can solve design problems much larger than current commercially available software. Moreover, since LiDO is built on existing LLNL simulation codes, it can be readily extended to accommodate additional physics, nonlinear and transient effects and multiple length scales. The shortcoming of LiDO is its lack of a user interface. LLNL would like to partner with a CAD company via an API to enable a software capability that allows designers to input a design via the CAD software, optimize its geometry via LiDO and then send it to a shop floor for fabrication via the CAD software.
- The LiDO code combines finite element analysis, design sensitivity analysis and nonlinear programming in a High-Performance Computing (HPC) environment that enables the solution of large-scale structural optimization problems in a computationally efficient manner. Currently, the code uses topology

optimization strategies in which a given material is optimally distributed throughout the domain. Originally the code parameterized the material's characteristic function field as piece-wise uniform over the finite elements, however this proved problematic when implementing LiDO's Adaptive Mesh Refinement (AMR) strategies. LiDO has since implemented higher-level parameterizations for the material's characteristic function field. One such parameterization uses the level-set function of an implicit geometry description of the structural component. Preliminary results using this approach are promising. To fully realize this approach's potential, LiDO must link to a computer-aided engineering (CAE) software that can provide the ability to model complex engineering relevant design geometries. This link will be in the form of an API. In this way, engineers can specify an initial design in the CAE software, have LiDO optimize the design and finally use the CAE software to send the design to the manufacturing floor for production.

- Advantages

  The key aspects of LiDO are its abilities to

  - Solve large-scale design problems via its HPC implementation
  - Use of AMR to ensure accurate simulations in a computational tractable manner
  - Its modular design which enables the easy implantation of, e.g. multiphysics, transients, nonlinearities etc.

  The key aspects of CAD are its abilities to

  - Model complex geometric components
  - Visualize these models
  - Interface with manufacturing machines, e.g. 3D printers

  This API project will develop a software environment that leverages the strengths of the LiDO and CAD softwares.

- Potential Applications

  There are several structural optimization programs that are currently available, but only the combined LiDO and CAD software environment will be able to

  1) Solve large-scale design optimization problems
  2) Utilize AMR capabilities
  3) Have user friendly interfaces to define initial designs
  4) Have user amenable interfaces with manufacturing process machines

- Development Status

  The LiDO code is still under development; however, it has been used to:

  1) Solve design optimization problems in excess of 1 billion design parameters
  2) Demonstrate the use of AMR
  3) Incorporate complex constraints, such as on the maximum stress.
  4) Use level-set type parameterizations

CAD Files & application handling.

For CAD managers keeping track of the barrage of CAD drawings models and associated files can be a real headache. When files are not managed properly, time can be wasted looking for files that might have been stored in the wrong place. Documents can get lost or overwritten, and models can be released prematurely causing significant, costly problems downstream.

As product data evolves and changes throughout the design process some form of a management system. Product Data Management (PDM) or Product Lifecycle Management (PLM), Aims to provide everyone involved with access to the correct and current version of the data, while simultaneously managing and tracking changes and the evolution of the product from cradle to grave. This has become more of a problem as design teams have greatly expanded both in size and in geographic location, adding more participants to the collaborative design process.

Establishing best practices for maintaining control and controlling access to product data can go a long way to help to minimize errors and duplicated effort. Some type of management system is essential to enable cross-team collaboration, control revisions, maintain an audit trail for regulatory compliance, maintain relationships between diverse files belonging to the same product and provide security and access to product data, Key capabilities are centralized document access, full text search, check-in/check-out, version control, audit trail, file relationship management and workflow automation,

Here are a few best practices to follow to help control the chaos.

1) *Implement a PDM or PLM system:* This might seem obvious, but these solutions, offered in PDM and PLM systems, will go a long way in helping manage your product data, offering built-in, automated features to control revisions, manage access and security, facilitate collaboration, create audit trails, and manage file relationships. etc.
2) *Establish a control process:* Again, this is essential if no automated solution is in place. This process will ensure that all employees are checking and making changes to models and drawings in a consistent manner.
3) *Store all models and drawings in one Location:* Preferably a shared network drive, if a PDM system is not being used its essential to create a good product structure tracking system. When making changes to files, copy the file locally first instead of making changes directly to the models in the shared location. This is will help ensure that released documents are not prematurely updated without going through the data control process. When changes to models are drawings have been approved, move them to the share location and update any references that should point to released data.
4) *Maintain consistent file naming and revision control standards:* Again, this is important if you are not using any type of management solution. Make sure you use unique names for files and use a project name or customer number as a prefix or suffix to eliminate confusion when multiple parts have the same name.
5) *Don't use revisions in file names:* If you have assemblies with a lot of parts, changing the revision level in the file name for parts will cause havoc with external references (in-context, mirrored, base parts. Etc.

Many of the best practices described above can at best be described as a band aid approach to solving data management problems. In reality companies who deploy PLM software solution will find the above best

practices are a core part of the capabilities of the system. Delivering an effective approach to solving data management issues.

Effective data management can help your users quickly find files, control revisions, reuse design data efficiently. Collaborate across multiple sites, automate workflow and approvals, and manage complex file relationships. Maintain an audit trail and comply with industry standards. All this will result in overall better business results through improved productivity and collaboration, higher quality, and streamlined processes that enable your company to be more competitive and profitable.