Session 3238

A Methodology for Developing Unigraphics Parametric Assemblies for Product Design, Tool Design and Analysis

John L. Irwin

Department of Design Engineering Technology
Mott Community College
Flint, MI 48503, USA

Introduction

Parametric Assemblies are an important element in the design process of a product or tool, because of the ability to continually update, and/or replace components in the assembly as the design changes through the design and analysis phases. One of the goals of the Design Applications course is that most course assignments will be in project form and come from industry. The challenge in this area is having active and involved program advisory panels that are willing to participate at a high level of cooperation with your program. At MCC we have had varied levels of participation from advisory committee members. Members are more than willing to give suggestions on project topics and possible design scenarios from their industry, but due to proprietary reasons, as of yet they have not been willing to share any parametric UG assembly files that we can use as a starting point for a real life industrial applications.

As a result, prior to the start of the course I visited three companies, which gave me ideas for industrial-based projects to use for this course. One company was Amigo Mobility International, Inc. a manufacturer of mobile devices for handicapped persons. Next, Acutech Industries, Inc., which is a product and tool design-service mainly servicing the automotive industry needs. The third company is a partner of the MCC Automotive Technology Department called Factory Five Racing Inc., which is a manufacturer of a Cobra kit car package. The problem still remains that none of these companies had 3D solid models of their product, which could be shared with the public, but they were willing to cooperate by sharing parts, ideas, and 2D drawings.

I met with an engineer from Amigo Mobility International who shared the 2D drawings of the seat cam locking mechanism and provided the seat and post parts of a standard amigo model for students to reverse engineer. The design problem that was developed out of this research was presented to students as the following: Amigo has contracted your design group to design a manually reclining version of the chair. The person with a handicap may want to recline for relaxation or need to recline for therapeutic purposes. The chair and post are available for reverse engineering and the locking mechanism 2D drawings will also be provided. A lounge chair linkage mechanism is also available to reverse engineer or for brainstorming design solutions.

An advisory panel member at Acutech Industries Inc. shared a project with me that they had developed for a customer who in their garage had invented a tricycle, which used hand cranks in order to assist locomotion for a partially handicapped child with little amount of leg power. This gave me the idea to purchase a standard tricycle that the students could produce a retrofit kit for to be used by a handicapped child. The designer assigned to the project at Acutech, a graduate of MCC with a degree in Design Engineering Technology, who explained how he used Solid Works software to 3D parametric assembly with an associative set of working drawings for their customer. Using this idea I created the assignment for this group, which looked like the following: Huffy Corporation has contracted your design group to design a retrofit kit for a tricycle. The kit is for a three-wheel vehicle that will be powered by hand locomotion for physically handicapped paralyzed from the waist down children from the age three to five years old. You are supplied with the original parts of the tricycle that the kit will be used on in order to reverse engineer and 3D model the parts necessary to create your design.

The Automotive department at MCC offers a course in the building of a Cobra kit car using products provided by the company Factory Five. The owner of Factory Five was very receptive in providing information to me for this project in order to promote an interdisciplinary approach to having kit car courses taught at our institution. In addition to having courses in how to built the kit car other disciplines in technology have been able to involve their students in kit car production class projects. The machine shop, CNC, auto-body and now design courses have been involved in kit car production projects, which give students practical hands-on application of their skills. There were many design concerns that the MCC automotive instructor and Factory Five representatives had with the design of the kit car. Redesigning the engine mounts, rear bumper, the battery holder, the dash board and the floor sheet metal in the passenger compartment to mention a few. Although, in order to create a group project to encompass the time allowed in the course I decided to concentrate the design to the drivers compartment seat arrangement. We were provided sketches of the frame, the sheet metal in that area and the seat in order to reverse engineer and create 3D models. The design problem provided to these students looked like the following: Factory Five has contracted your design group to design a new driver compartment seat arrangement that will move forward and back and rotate the seat 90 degrees and lock into position for exiting the vehicle easier. In order to design this product you will be provided kit car frame sketches, sheet metal panels and the seat to 3D model using UG.

Bottom-up Assembly Approach

The first phase of the project involved students in three groups made up of eight students each creating 3D parametric feature based models of each component of the existing design. I stressed the importance of the models being parametric, because later in the course they may be involved in making some design changes on the original components. The students divided up the parts and got to work creating their models that were then deposited in a common public domain directory. One student found it easier to use a Web based collaborative engineering site to upload his models to so that other students in the group could access his files. Once completed, each student created a flow chart on paper showing how the assembly and sub-assembly structure would be represented in his or her project. Then, each student using File – New and naming the files appropriately created the assembly and sub-assembly virtual files. First, with the sub-assembly as the current work part, the components were added and each part was retrieved from the public directory and repositioned into the correct vehicle location. Then, with the main assembly as the current work part, the sub assembly and additional components were added and repositioned similarly. When the assembly and sub-assemblies were complete, mating conditions were added to components to adhere to possible design changes that may occur during the design process. This process gave the students a framework of geometry to design their solution to the problem presented them using accurate information to design around. Solid geometry Reference Sets were created in the component part files in order not to clutter the assembly file with curves or reference geometry by filtering out the Reference Sets when creating the assembly file.

While the students were reverse engineering the parts and creating 3D models for the project they were also researching on the Internet similar designs and products that could be utilized in their designs. In this stage the groups also brainstormed and discussed their preliminary ideas. Each student was required to come up with a minimum of five preliminary design solution alternatives. The groups also developed a concept selection matrix based on the objectives of the project. After researching and brainstorming, each student presented to the class a sketch of their favorite preliminary design solution to the group. The other members of the group rated the solutions to the problem using the matrix on a scale of 1 through 3 with 1 being high and 3 as low. I then used these results to group two students together who had similar ideas or who had designs, which complimented each other. The two students then worked cooperatively to refine their design solution.

Top-down Design in Context Assembly Approach

At this point in the project the design sketches had been refined to incorporate ideas from both members of the group and input from the class and myself. The students were asked to group the newly designed parts into two separate sub-assemblies that would be added to the main assembly file. Each student would then be responsible for creating a parametric top-down approach sub-assembly. With the new sub-assembly as the work part, virtual files were created for new purchased and manufactured parts to be added to the sub-assembly. Finally, one component at a time made as work part, the parts were modeled ***in the context*** of the assembly in reference to an established main assembly coordinate system and existing geometry. This procedure is very important to the goals of this course to provide students with an industry-based project that the student can create a design solution using existing 3D geometry. After the sub-assembly was created each member of the group saved it in the public directory for retrieval. The resulting sub-assemblies were then retrieved and added to the main assembly using the bottom-up approach sited in the last section. Each student could check the other group members' portion of the design for function, clearances or interference at this time.

One of the requirements of the course is also that students develop a design proposal paper and present their design solution in a presentation format. The design proposal paper required one paragraph on each of the following topics: problem identification, selection criteria, preliminary ideas and preliminary design. The presentations could be either done using PowerPoint or overhead transparencies made from downloaded image files from the UG assembly. Students created GIF shaded images that were saved to their accounts and either emailed to a PC with PowerPoint or plotted to transparency paper for overheads. These image files were used to explain to other members of the class their cooperatively created preliminary design solution. Next, the two-person team presented their design solutions to the group this time using the 3D models to illustrate their ideas. For additional input on their design I invited the advisory group members who had originally given me the ideas for the projects to help critique the designs. The volunteering advisory panel member used the same selection criteria matrix used in the last section to rate the designs. This system paralleled what I had experienced in industry in customer design review meetings.

Design Refinement and Analysis

After input from advisory panel members and myself changes, additions and subtractions were easily made to the assemblies because of the parametric capabilities in UG. With mating conditions made on parts in the assembly, if a part is updated to be longer or shorter the mated parts automatically adjust to the new location in order to stay mated correctly. Additional refinements were made on parts as students investigated material selection, manufacturing processes, production concerns, quality issues and the like as related to the project. Students in this section were required to write a design analysis paper which included as related to their design a paragraph on the following topics: property analysis, mechanical analysis, functional analysis, human factors, aesthetic analysis, market analysis, and financial analysis. Most of the focus of this course using computer graphics pertained to the first four of these analysis factors.

Property Analysis

Each group included weight as selection criteria for their project, because the lesser the weight being added to the entire system the greater the efficiency of the overall designs. Property analysis is based on physical properties such as strength, size, volume, center of gravity, weight, center of rotation, as well as thermal, fluid and mechanical properties. Having a part modeled in UG in 3D solids lends itself to being able to perform solid property analysis of parts very accurately. Using charts from the Machinery's Handbook physical properties of materials were researched and input to replace the system default, which is for steel. Then using Analysis – Mass Using Solids the part can be selected to list all the physical properties mentioned earlier except for strength. Finite element modeling of the parts under loads and conditions is beyond the scope of this course, but is possible using finite element analysis software. Designs then can be refined to accommodate forces that result under stresses during operation of the design. For this course students were required to list the weights and materials, copy the list into the clipboard, and print the results for each new part being added to the project. Entire assemblies and/or sub-assemblies were also be analyzed for solid density in UG using Analysis – Assembly Weight Management in order to support the design criteria required for their project.

Mechanism Analysis

This type of analysis is concerned with the calculation of motions and loads in mechanical systems comprised of rigid bodies connected by joints. Mechanism analysis includes assembly, kinematics, and dynamic analyses. Using Analysis – Assembly Clearance and choosing the parts to be analyzed students explored interference between component parts in an assembly. Kinematics and dynamic analysis was performed on specific parts of the designs if necessary to determine clearances during the operation of the mechanism. Kinematics analysis is a very time intensive study, and therefore if not necessary to validate the design it is eliminated from the design process. In one instance, the kinematics analysis of the handicapped tricycle project determined the length to make specific components in a hand crank mechanism. In other designs parts were repositioned within the assembly to evaluate design clearances at different positions in the movement. For instance, the kit car seat needed to be repositioned 90 degrees in the drivers' cockpit in order to analyze whether there would be sufficient clearance to the side panels. Human factor analysis using ergonomic simulation software would have been helpful in the analysis of the designs for this project, but extended beyond the time and scope allotted. Although, students did consider during the design process the ergonomic requirements of ease of use, ease of assembly and ease of manufacture. The Aesthetic analysis was partially determined using the functions in UG, which enable the user to modify the color of parts to resemble the final finish required. Students used Edit – Object Display to change part attribute colors to match customer requirements.

Associative Product Assemblies and Details

Once the designs had been refined using input through review and analysis it is on to the documentation stage of the design. The students were required to produce an assembly sheet including the manufactured and purchased parts in their sub-assembly portion of the design. If an isometric assembly was preferred they created an exploded view first in modeling using Assemblies – Exploded Views. Each part in the assembly was identified and a bill of material was created to record the parts. Details were created in a similar fashion with the necessary orthographic views and an isometric view. Each manufactured part was fully dimensioned; tolerances, GD&T and notes were also applied depending on specific manufacturing requirements. Along with the submission of the detail drawings, manufacturing process routing sheets were required listing the steps in sequential order for the production of the parts. This assignment fulfilled the course requirements to also be concerned with design for manufacture and design for assembly matters. The assembly and detail drawings were submitted for further review following which; revisions, additions and/or deletions were made to the designs. Again, because of the parametric ability of the assembly corrections were easily made by the students to update the model and associative drawings.

3-D Tool Design

Traditionally, in the automotive industry 3D parametric modeling has been confined to the product designers, because of their need to visualize parts and analyze designs. Traditionally in tool design the designer will create orthographic 2D views of the part from a UG model in the position that it is to be loaded into a fixture, jig or gauge to be designed around. Then, using a 2D CAD software package the designer would create a tooling design around the part by locating clamps, locators, bushings and material to hold the part in place for the manufacturing process. The problem with this system is that interferences between parts is difficult if not impossible to detect. Presently, the trend is shifting to 3D tooling designs for the same advantages found by product designers. Also, with manufacturing simulation being the trend in the automotive industry, tooling suppliers are being required to deliver 3D tooling that can be used in the virtual manufacturing software packages in order to simulate the tool opening and closing on the product while the product is being loaded for production. Entire assembly work cells can be simulated and tested for collisions and robot programs can be downloaded using accurate 3D product and 3D tooling models. This process has been used widely in the aircraft and automobile industry and is likely to spread to other high production/high precision industries.

To prepare for the design of the tooling in this project, students were required to create manufacturing routing sheets for each new part of their design. In addition to the process description, an area was included for the designer to sketch ideas for fixtures, jigs or gauges to be used to hold the part for a specific operation. After review of the sketches I suggested the tool that the student should develop for their design. The tooling chosen was simple enough to be completed in the time allotted. So, I eliminated any sheet metal die or injection mold designs from the scope of this class project. Similar steps used earlier in the course for product design were used for the tool designs. The tool assemblies were reviewed for the following criteria; design in context parametric assembly, product part shown in position, purchased tooling components, manufactured detail components, feasibility of design, produced economically, adherence to routing sheet process, serviceability, clamping principles and locating principles. Previously created 3D UG models of standard tooling components were added to assemblies using the bottom-up approach allowing students to complete tooling models faster than if all components would have had to be modeled in the context of the assembly.

Documentation of the tooling design followed a review of the models and subsequent modifications. A similar process was used to create associative drawings as discussed earlier for product drawings. Product part profiles in phantom were added to the tooling assembly drawing as a view dependent editing function. An important part of the tooling drawings was that they used the same product model that was used in the product assemblies, so it was the most current version of the product and would reflect any subsequent product changes.

Engineering Change Notice

A change notice was introduced in the final week of class to make a change to the part that fit in the tool as a final test of the parametric capability built into the students' product assemblies, tooling assemblies and parts. The test was that if the parts were modeled correctly, the change could be made easily and mated parts would adjust in the subsequent assemblies. For instance, in one group's design the seat post of the Amigo design, which had two holes added to accommodate the retrofit kit was changed to be two inches longer. After changing the product part I looked for the following results: Did all the parts update to new locations in the product assembly? Did the drill jig parts conform to the new length of the part in the tooling assembly?

With a small amount of modifications on other parts the change notice should be easily made using the parametric assembly and associative drawings.

Teaching Pedagogy

The system in which the students performed their tasks was very facilitator driven where I became more of a resource person than an instructor when groups were struggling with a design decision. I think that most of the learning that took place was through one on one design reviews with students after their presentations. The educational benefits incurred by the students taking a concurrent engineering approach to this project enabled the students to work more effectively in groups. Starting with a group of eight students, having them rate each other's designs and grouping them together in groups of two that had similar ideas worked to make the groups work together more cooperatively. The use of technology in this course, such as researching using the internet, sharing files from a common location, accessing standard product models and exporting image files to be used for presentations expanded the use of the computer for more than a CAD tool. The writing of papers and giving oral presentations achieved the college's general education goals of writing and speaking across the curriculum. The constant design revision process that occurred during the design process reflected the reality that design is dynamic and not complete after an assignment is turned in for a grade. Parametric assemblies are introduced in a beginning UG course, but many students commented that without having a chance to do a semester long project they really did not understand the benefits and full capabilities of a parametric assembly. Especially, when it came to the creation of the mating conditions thinking about the future part changes that may occur.

As in most courses the student outcomes from this course were directly proportional to the effort put into the projects. I graded projects on a competency-based system. The students were given a checklist of items that needed to be met for each project and until it was satisfactory they did not earn the credit for that competency. Some students strive to continually redo assignments to meet all competencies and others are satisfied with 3 out of 5. Although, all students were grateful to at least have the opportunity to meet all the competencies even though they may not have had the time to complete necessary revisions. A solution to this problem in the future I think would be a more detailed rubric for the rating of each of the five criteria, and a minimum requirement for being able to move to the next step in the project. The amount of time in the semester to accomplish this approach is always a concern, because some students invariably take more time to meet your expectations than do others.

Conclusions and Findings

My findings from teaching this course are as follows; that a well thought out project is the key to the success, an enormous amount of time is spent outside of class critiquing and checking the progress of projects, and knowledge of the capabilities of UG is paramount to coordinating groups of students working on all different projects. I was not able to model up the answer to the project before class in order to anticipate the questions that students would ask. One student asked me about half way through class, "You mean to tell me that you haven't used this project before and you don't know how this design is going to work? Then how do you know what is the correct design?" I answered, "The benefit that you are going to get out of this project is knowing that you designed, analyzed and completed a successful design as a member of a design team supported by your own research." I believe this course gives students the confidence to become a ***designer*** in the future rather than remaining at the level of a layout drafter or detailer.

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Biographical Information

John L. Irwin is an Associate Professor and Program Coordinator in the Design Engineering Technology Department at Mott Community College (MCC). He holds an A.A.S. degree from Michigan Technological University in Mechanical Design Engineering Technology, a BS degree in Technical Education and a MS degree in Occupational Education from Ferris State University. He currently is pursuing a Doctorate of Education Degree in Curriculum and Instruction from Wayne State University. In addition to his college courses, he has taught numerous industrial training courses for local automotive employees in Unigraphics modeling and drafting. His current research is in the area of Manufacturing Simulation Technology as a developer of curriculum and Project Manager for a N.S.F. sponsored project to develop methodologies for teaching and applying robotic and manufacturing simulation technologies using Unigraphics models.