

2018 ASEE Mid-Atlantic Section Spring Conference: Washington, District of
Columbia Apr 6

Identifying Boolean Logic Processes via the Basis of a NACA 2415 Airfoil

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Identifying Boolean Logic Processes via the Basis of a NACA 2415 Airfoil

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Abstract.

The development of models via CAD software have arisen with the advent of programs such as Autodesk, Solidworks, and Creo-E. To better utilize this software, knowledge of how to use said CAD programs are necessary in order to develop and model structures for applicable use in the real world. The focus is then to understand the use and application of this software in engineering modelling. For this project, a model of an acquirable NACA airfoil and its geometry were to be gathered from academic sources and databases. Once acquired, the airfoil would be modelled using the CAD software into a 3D Printable object. The object's data would be inputted into Solidworks, after which a model would be drawn using Boolean techniques to draw holes and indentations, and using extrusion methods to develop shape and structure into a 3D environment. More importantly, understanding the process that is taken the develop the models necessary can lead to a method of automated Boolean processes for creating models without the need of the user to apply such processes post-modelling.

Keywords and Terminology:

Computer Aided Design, Boolean Logic, Extrusions, Sketch

1. Introduction

The advent of manufacturing techniques necessary to create and construct materials for use in many industries, whether it is used for printing components medically for implants, or in aerodynamic facilities for printing pressure gauges and electronic transducers, has resulted in the need for younger or enterprising audiences to learn the software used in these fields. The access of such tech has fallen to specialization roles, where people would defer time to designers and architects to develop what is needed. The field of mechanical, let alone general, design will be necessary for future companies and businesses, or even for printing laboratory equipment, as the processes and science respectively catches up to the industry.

However, whilst the science, math, and engineering components are catching up, the technological side is faltering. More time and effort is being pressed onto designers, and the field has pushed forward to where the design work is brought upon those who deal with the experimentation of the fields. Not many directions are given clearly on how to design or apply what is engineering drawn into the program efficiently, so this project focuses on applying two-dimensional drawings from data acquired from a database (in this case, the database is that of airfoil coordinate designs from the University of Illinois at Urbana-Champaign) and shows the process and techniques in creating models of such drawings. The process and methods shown in this paper can be applicable to most engineering drawings that rely on database coordinates and

schematics, or can be applicable to created schematics made from charts and spreadsheets. Additionally, while this paper will cover creating the models in Solidworks, other programs can utilize the same method of curve creation to develop the drawings into a model as well, but this paper will highlight how to create the models through Solidworks.

Lastly, this process has importance in a future project that will pertain to researching a Boolean Coordinate-Logic System that can be drawn straight from a PDF or Excel sheet for future drawing – this, of course, will allow for automated drawing without the need of human input to modify/input post-model.

2.1 Application -- Methodology

In order to develop the models, a method to follow is needed in order to ensure that the models are created correctly for engineering/scientific purposes. To demonstrate, a flowchart is shown below to show the process in modelling the drawings. This flowchart provides more than just a demonstration: it can be utilized in the future as a logic chart a program can take to draw models without the need of proprietary sketch software.

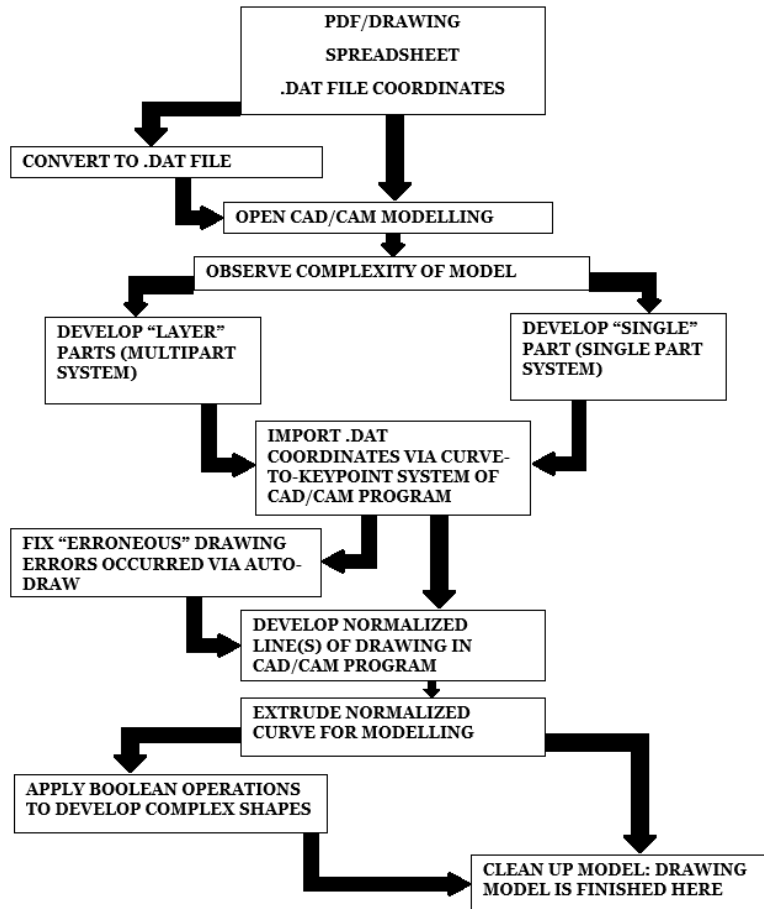


FIG 2.1 Methodology Flowchart for Modal Drawing – Process

Application – Introduction

First, let us develop the coordinate file necessary for modelling.

If one is already made and available for usage in CAD programs, then utilize it: otherwise, the coordinates will have to be converted to a database file (.dat) before usage for CAD programs. Some CAD/CAM programs already have Excel-Based coordinate systems built in, but for this demonstration of using Solidworks, such a feature is currently not implemented in yet, so a demonstration of conversion is necessary.

To begin, a coordinate file must be acquired: one can be derived by the user through Excel as needed, but in this paper, the coordinates are acquired via an aeronautical camber data points from the University of Illinois-Urbana at Champaign’s School of Aeronautical Engineering: specifically, the data points of the NACA 2415 Airfoil were acquired from UIUC’s Database of airfoil coordinates³, and in utilizing the data points, a model can be drawn and implanted directly to a CAD program. Realistically, this can be applied from any program standpoint via PDFs, Excel Sheets, etc.

Acquire the coordinates as a .dat file, then open said file into Excel. Once opened, we will develop the coordinates of the file to be input onto a text document for uploading. We first set Excel to define the .dat file as a fixed-width column system. Once done, we then take the file’s coordinates, subtract any extraneous information (like titles or additional non-numbers), apply a 3rd column of z coordinates (for this demonstration, it’s just projecting itself on the xy plane, therefore z is zero for all coordinates), then save the file as a Text File Delimited (Important, as this makes it retain values and their positions respectively).

Now, we can utilize the file and upload it to the CAD Software for developing the model. Start by opening the software in question (as again noted, this demonstration uses Solidworks). Then open the CAD program under whatever mode is needed to open the file (in this case, Solidworks – Part – IPS System). Then, we’ll navigate to the Curve Through XYZ, and we’ll extract the coordinates from the .dat file we created.

To develop the curve from the created .dat file, navigate to the “Curve Through XYZ” option. Browse your computer for the .dat file, and open it from the “Browse” option. If the text file was made correctly, coordinates should now appear within the CAD/CAM coordinate space.

In process, this is where a Boolean Logic table can be utilized, as it would remove the need of the end-user to develop and refine the model when it already has its coordinates drawn, but as to be demonstrated later, sometimes flaws exist with the model.

2.3 Application – Modelling

The points-to-curve generated should look pretty clean, but often manufacturers or designers don't account for CAD/CAM programs to auto-close gaps in the curve of the components. As an example shown below, the NACA2415 Airfoil's Coordinates do not auto-close the region that their coordinates end at. Therefore, the user will have to force close the edge via drawing a tangential circle from the CAD/CAM program. Once closed, the curve will need to be normalized, as it is considered bulky and straight-edged: this can be done via Normalizing the Curve. Then the curve can be extruded.

In process, the program can be taught to extrude a set unit amount dimensionally. By the end user's action, it would have to be done manually, often with oversight that there would be holes or issues with the design. To therefore teach the program how to follow the 'normal' of the line and create the needed design fixes would remove tedium on the end-user to fix what should already be processed or fix, especially if the error in drawing is minute like a small hole. Additionally, by analyzing the methods that a human can model, a machine can also replicate and draw without the need of said technician to draw the images, removing the necessity of the technician to fix said errors. Having the machine or program then draw the developed curve automatically to what is needed is then a benefit of having a fixer of sorts.

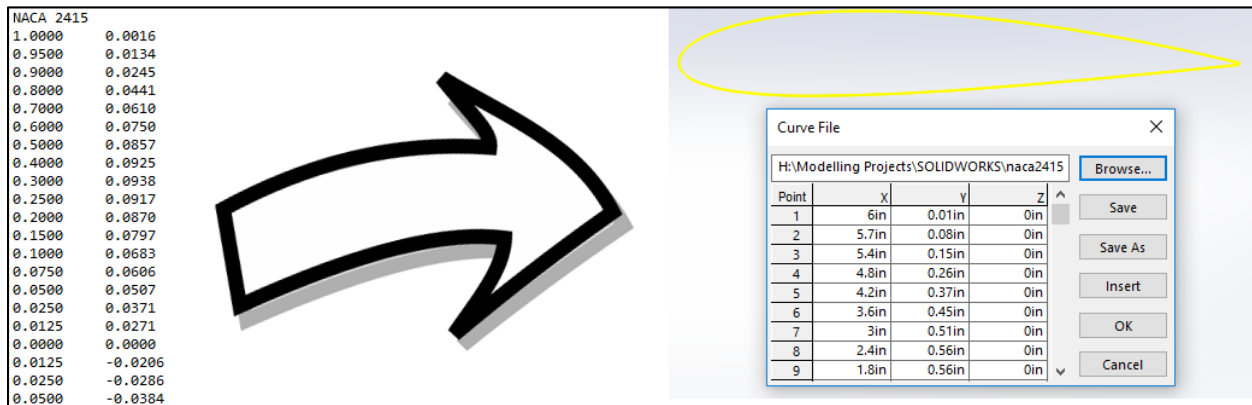


Fig 2.2 Coordinate-to-Model Process Flowchart for Developing CAD Model

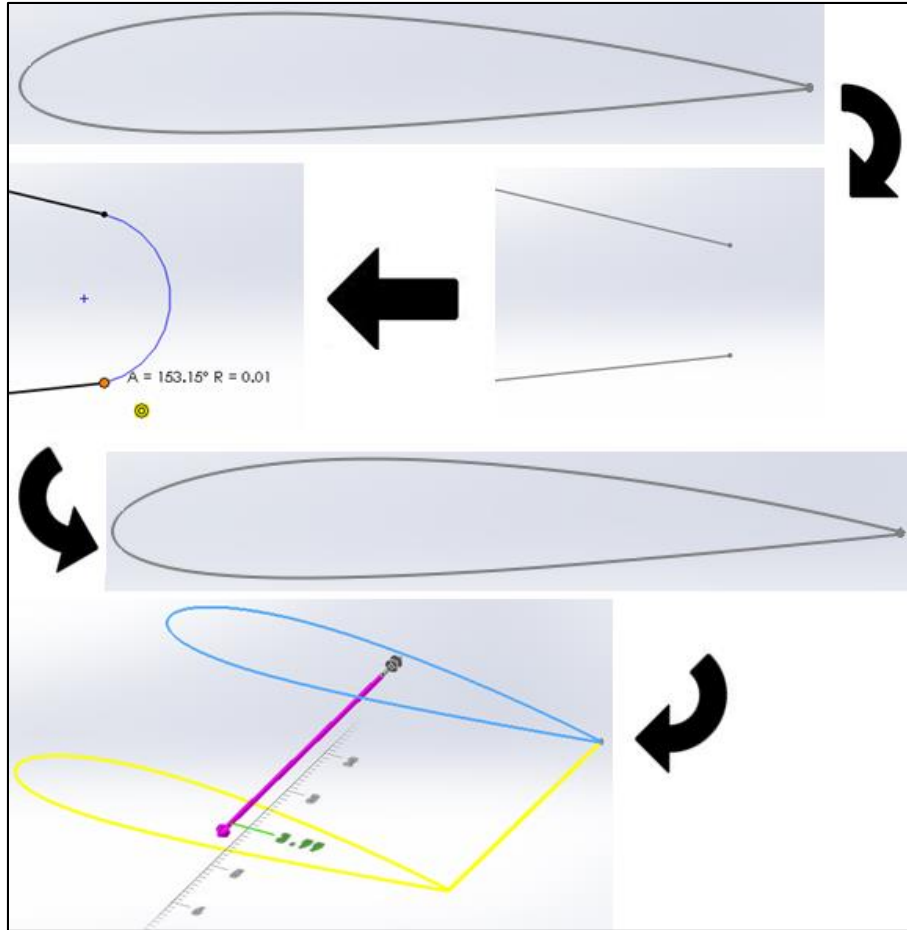


Fig 2.3 Modelling Flowchart For Refining and Extruding Designed CAD Model

2.4 Application – Boolean

Say the user wants to print the object in question for mounting and testing in a lab, in order to calculate, draw, and analyze lift, drag, and Reynolds information of said airfoil¹. To do so, one would need to remove a section of the airfoil to install a rod to mount said airfoil in a wind tunnel. Therefore, Boolean logic is needed here, as a region for a rod to be installed will have to be cut from the main airfoil design. However, it should be noted that it's ultimately up to the user if a mount should be installed in a prime location, as this can theoretically be applied anywhere on the model's face curvature.

Start by identifying a location where the mount will be located. Once found, locate where the middle point of the mount will rest on the face. Using the CAD/CAM's Sketch tools, the user can cut and extrude a section for the rod by drawing a circle from the middle point location to a defined radius². Then the Sketch tools can be used to cut an extrusion of that circle through the material. Voila! The material now only needs installation in the real world for use in wind tunnels.

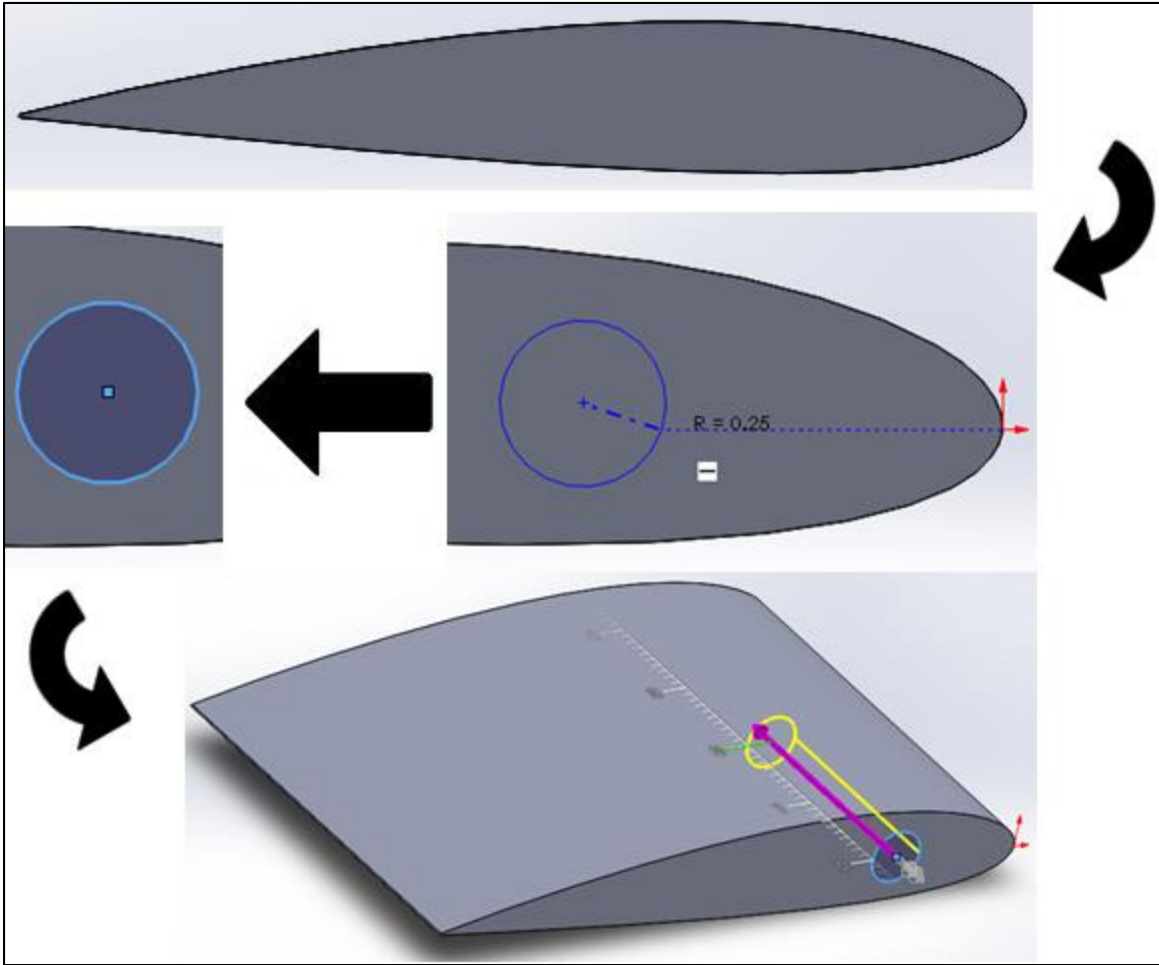


Fig 2.4 Boolean Flowchart to Develop Extrusion Cuts (Subtraction Method)

3.1 End Result

At the end, the following result should be as below for the finished model. As seen, it appears clean and identifies to that of a standard NACA 2415 Airfoil.

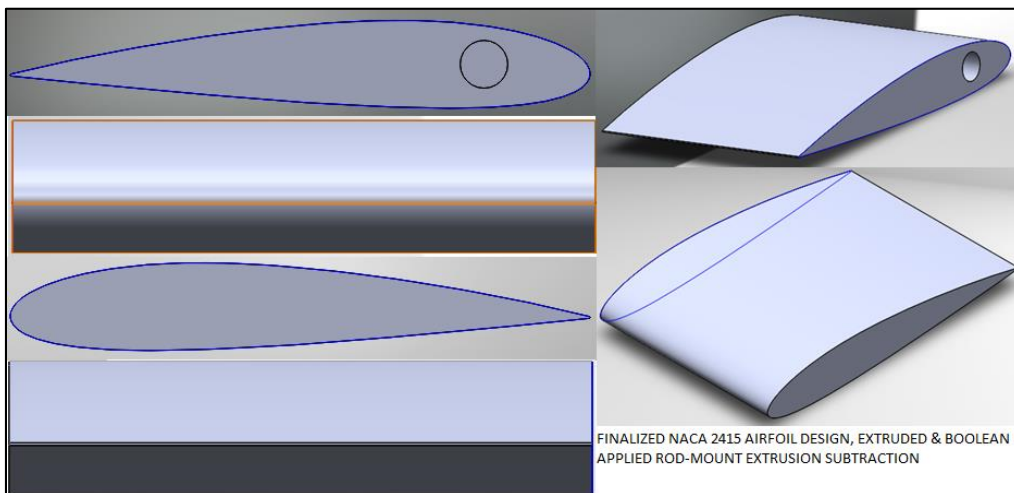


Fig 3.1 Final Resulting CAD Design with Boolean Applications Applied

3.1 Conclusion & Forethoughts

Overlooking the project, it appears that the process to draw coordinate-to-model is very tedious: for starters, Database files are clunky and not well utilized in the scheme of modeling in today's world, for many of the drawings conducted on machinist and factory floors rely on already-present technicians to draw the files. Another fault of the database files is their archetype: the files are not designed for coordinate translation. While some CAD software may be able to (partially) read Excel sheets and PDF-based coordinates (such as Autodesk's AutoCAD, Parametric, and Creo-E), the process is not refined and has flaws for the end-user that would require polishing: a great demonstration of this would be the NACA Airfoil selected: programs do not process that curves need to be closed, so the user would need to normalize the line and close said curve for usage. This means that the user has to spend time to scour, zoom, and trace objects given in order to ensure they're properly closed and modelled correctly for processing. This impacts CFD/Modelling Analysis even further as such small holes can compromise usability in the programs due to the incomplete structures.

The process is acceptable for use as a coordinate-only drawing scheme, but it lacks polish: the idea for it may have been introduced with the prospect of GD&T (Geometric Dimension & Tolerance) via coordinate/database files, but it feels as though it was left intentionally vague without modification. Therefore, further processing of this element may be necessary.

Additionally, this system has incredible use if the logic can be fixed: having the capability for the user to administer and process a coordinate straight into a model from nothing more than a PDF or Excel file can dramatically reduce the time needed of a technician to process errors and redefine the model for use, and it can further reduce the need of the end user to draw and design the already-coordinated file. For this to be truly utilized would require the use of a Boolean Logic table, or process that can be defined via coordination that can then be transferred directly to CAD/CAM programs for usage. Otherwise, the same issues lay apparent when processing many different coordinate points at once.

Further research and studying of how the CAD/CAM programs can process database files strictly for Boolean Logic would be needed to usurp this issue. Furthermore, an effective way of testing database files are needed to prod for any discontinuity in the design, but this can be alleviated with the Boolean Logic from the file. When this can be addressed, the process of straight-plotting coordinates to a 3D Model will be faster and more efficient, and therefore lead to less error on complexity of design for the end-user. As well, it can allow for alleviation of machines or AI-inspired programs to draw without the need of technician support.

4 References

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2. Howard and Musto, Introduction to Solid Modeling using Solidworks 2017, McGraw Hill.
3. "UIUC Airfoil Coordinates Database." UIUC Airfoil Data Site, University of Illinois-Urbana at Champaign, < m-selig.ae.illinois.edu/ads/coord_database.html >.

4.x Biographies

4.1 Alexander Wray

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4.3 Connor Feeney

Connor Feeney is a recent graduate of Purdue University of West Lafayette. He has a B.S. in physics, a minor in psychology, and he intends on starting a master-program in mechanical engineering with PNW in the fall. He conducted undergraduate research with the Dark Matters Lab, working on dark matter detection techniques. He currently works as laboratory technician for PNW's engineering department.