Training the Active Duty Naval Workforce using the Digital Thread to Design/Redesign Basic Models with Validation Through the Additive Manufacturing

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Abstract

This digest will showcase one approach to teaching engineering graphics and design for the active duty naval workforce. Sailors are exposed to solid modeling fundamentals during the two-day long workshop. Solid modeling is taught in connection to concepts of digital thread and design for additive manufacturing. Engineering graphics fundamentals are introduced with the emphasis on a deeper understanding of machinist approach, often used for an easier understanding of Boolean algebra, which is embedded within the Computer Aided Design tools and discusses how the design for additive manufacturing would differ from that approach. Moreover, special attention is given to understanding the impact of design decisions related to the constraints of the additive manufacturing system, including materials, size, shape, direction, temperature, different print head trajectories and other settings in a digital manufacturing system. This comprehensive, iterative process provides opportunities for design improvements and the use of digital thread for the development of future workforce for the naval enterprise.

Introduction

Engineering graphics is well established in various curriculum at different levels of instruction, ranging from the high school setting, career and technical education setting, community college, and beyond to the university setting. Different courses are also designed for incumbent workforce. Some courses are taught by engineering services firms that are basically a point of contact for the software companies; they maybe managing accounts and making sure that industry is receiving up to date training for their daily operations. Most of these courses are focusing on the specifics of engineering graphics and on specific tools that are embedded in a specific software. Some also cover engineering graphics fundamentals and the fundamentals of standards that are used in engineering to manufacture parts and assemblies, which are embedded in engineering drawings. These courses are usually developed for an incumbent workforce that already has some technical knowledge and often has some previous training in either basics of engineering graphics or two-dimensional engineering graphics software. The training presented in this digest differs because it was made for active duty military, some of which are in the technical workforce, such as electricians or mechanical technicians, but some who are working on completely different jobs that do not require a lot of technical knowledge. Another limitation is that this workshop only lasts two days, in which multiple topics other than engineering graphics are covered to include: additive manufacturing, slicing and G Code preparation, material selection and material properties, and reverse engineering. The main goal of this workshop is to expose naval workforce to additive manufacturing technology, along with solid modeling and reverse engineering. The main objectives of the computer solid modeling part of this workshop are to: Introduce students to parametric modeling and feature based design; learn about features extrude, hole, and fillet; learn how to edit and modify dimensions on 2D sketches and 3D features; learn how to delete features, change order of features in the model browser; save files and export designs into *STL files.

Introducing Additive Manufacturing to an Active Duty Military

The first topic that was introduced to the naval workforce was additive manufacturing and the applications of different additive manufacturing technologies within the United States Navy (Arcaute, 2018, Audette, 2017a, Audette, 2017b, Jovanovic, 2017; Nassar, 2013; Scheck, 2016). Sailors also had a hands-on session with fused deposition modeling technology and am additive manufacturing system where they printed a logo designed for this workshop. In this way, they were exposed to the main subsystems in a 3D printer: an extruder, a spooling mechanism and a printing platform. They also learned how to control the main machine interface and select files that will be printed, to check for machine leveling and to observe the 3D printing process.

Introducing Computer Aided Modelling to Active Duty Military

Computer Aided Modeling was introduced with a discussion about the digital thread that gained attention in the naval enterprise as a response to constantly changing the naval fleet, the ways that naval vessels are being manufactured, and the ways that naval vessels are being maintained, which is part of a larger digital engineering transformation that is happening across different Department of Defense units (Zimmerman, 2017). Sailors were introduced to the new class of naval carriers designed with the use of digital thread. There was also a discussion about the future possible use of digital thread for maintenance operations in terms of having some of the temporary spare parts available that would enable smooth running of naval operations.

Hands-on activity was focusing on step-by-step instruction related to the creation of their first parametric 3D model – a keychain. Sailors modeled a keychain that they would slice and then create a G code for the 3D printer. A keychain was generated in 6 simple steps. Sailors had the following resources available for this activity: a 5-minute-long YouTube video, a printed slideshow that the instructor was using, and the demonstration and step-by-step guidance by the instructor, who is teaching the Computer Solid Modeling class at her institution.

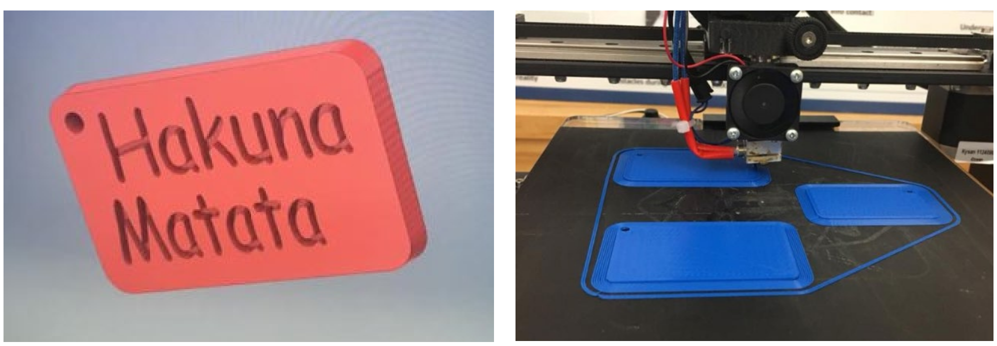

Figure 1: A) An example of the keycahin design; B) Three keychains during the 3D printing process Arcaute, 2018, Audette, 2017a, Audette, 2017b, Jovanovic, 2017

The whole keychain activity lasted only one hour and was delivered in the same way to the fifteen workshops throughout the span of three years, averaging 20 sailors per workshop. This project was funded by the Office of Naval Research STEM office. The main purpose was to start developing a new skillset in the naval workforce related to the advanced manufacturing, reverse engineering, and computer solid modeling.

The keychain model was created alongside a discussion of parametric 3D modeling fundamental concepts, related to designs that are created with the feature-based modeling principles. These principles were introduced with basic 3D modeling components, such as extrude, or modified ones as fillet, and hole features. They discussed the machinist approach used in 3D modeling and Boolean operations that are behind add and cut options in the Extrude feature when they were embossing or adding the letters on their keychain. Students reviewed print time needed for a keychain made with the embossed letters or the letters that were added on the top of the first extrude. The class and instructor also discussed G code and how design is connected to the print time and running of the 3D printer

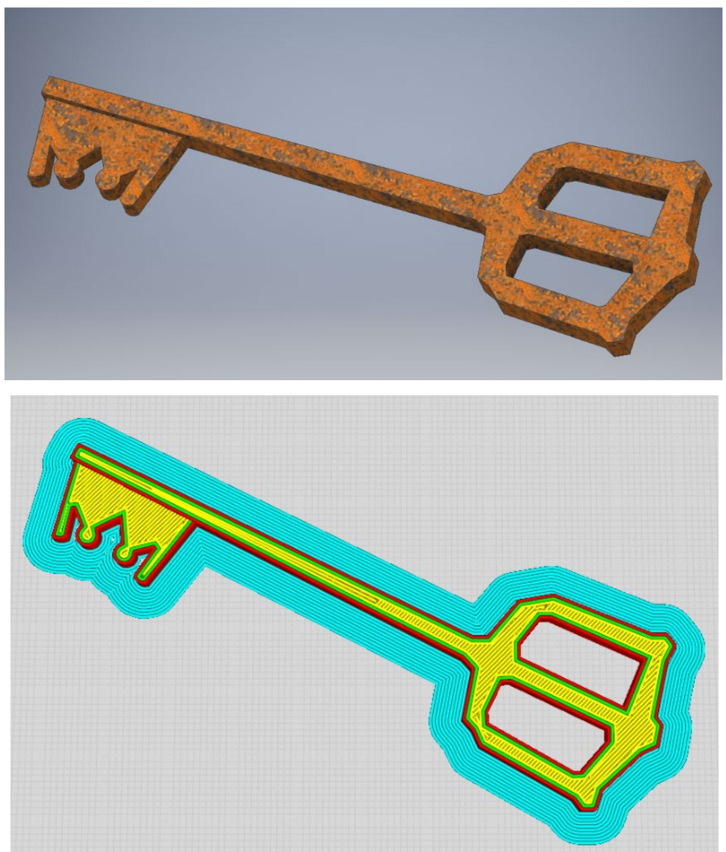

Figure: An example of one the designs created by one of the sailors in the workshop # 15. A) Parametric model in Autodesk Inventor, B) slicing of the design in the Cura software and review of layers created in a G code that are going to be deposited on the 3D printer's platform – design was revisited to make sure that there are enough of the layers Arcaute, 2018, Audette, 2017a, Audette, 2017b, Jovanovic, 2017

Active duty military from the U.S. Navy participated in 15 workshops that were held at the Old Dominion University, Norfolk, Virginia (Arcaute, 2018, Audette, 2017a, Audette, 2017b, Jovanovic, 2017). The first day included one-hour 3D modeling activity – the keychain activity. The second day included 4 hours of Reverse Engineering in Computer Aided Design workshop, which entailed 15 minutes of introductory lecture with 45 minutes on demonstration and hands on, and 3 hours of open lab activity in which sailors designed their own designs that were then exported as *.STL file, imported in the slicing software, created G code file, and then printing on the available fused deposition modeling printers. In the second day, they were able to print their initial designs, and then perform design iteration to revise and change various dimensions or features so that the 3D printed version of their design would be improved. Some of the fonts chosen could not print well or the size of the letters was smaller than 3D printer resolution.

Conclusion

Five hours of introduction to CAD modeling was delivered through the 15 workshops held at the Batten College of Engineering and Technology, Old Dominion University, Norfolk, Virginia. The whole workshop was 16 hours long, and it included additive manufacturing fundamentals, reverse engineering fundamentals, and materials and their properties fundamentals. Learning activities designed for this workshop are now embedded within the Computer Solid Modeling course taught at the same university within the Mechanical Engineering Technology program. Modules are also used within the U.S. Navy to train their personnel.

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