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Bringing the Humanities and Engineering Together through Multi-disciplinary Senior Design team projects

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Abstract

Every Engineering student at the Rochester Institute of Technology must complete a senior capstone project as a condition of graduation. Most students fulfill this requirement in the form of a two-semester, Multi-disciplinary Senior Design (MSD) team project. These projects are designed to provide the students opportunities to apply their classroom training in a collaborative environment.[1,2] The multi-disciplinary teams bring together students with varied skill sets in projects that require them to assess customer needs, establish engineering requirements, benchmark existing solutions, evaluate possible concepts, and apply engineering practices to design, build, test, and document a working prototype device or process. See the MSD program website for further information.[1]

The projects undertaken within the MSD program cover a broad range of applications, with sponsors including the National Science Foundation, Wegmans, Boeing, and ABVI/Goodwill. In recent years, projects undertaken in this program have included several efforts in conjunction with cultural heritage institutions. These include a streamlined manufacturing process for micro test targets for Image Science Associates, an update of the Image Permanence Institute's data logger, which is used to monitor the temperature and relative humidity in archives and libraries, streamlining of the George Eastman Museum's 2D artifact digitization process, and construction of period-appropriate replicas of a 18th century printing press and 16th century reading wheel replicas for the Cary Graphic Arts Collection at RIT and Rossell Hope Robbins Library at the University of Rochester. This report will feature the Reading Wheel project to illustrate what the projects involve and how they can be used to bring the worlds of the humanities and engineering together.

Introduction

The Multi-disciplinary Senior Design senior capstone course was designed to bring together students of various engineering disciplines to work together on teams tasked with real-world projects. This initially involved Mechanical, Electrical and Industrial & Systems engineers. The program then expanded to include Computer, Biomedical, and Chemical engineers, as well as Industrial Design, Imaging Science, Biomedical Imaging, Physics, and Museum Studies students. There has been a spate of recent projects that have expanded the scope of the program to include devices and processes of interest in the Archiving world. This began with a camera rig project sponsored by the Metropolitan Museum of Art. It was followed closely by a test target production process optimization project sponsored by Image Science Associates, Figure 1. The most recent projects to be undertaken are initial work on updating the Image Permanence Institute's data logger, process optimization of the George Eastman Museum's 2D artifact digitization process, and the construction of 16th Reading Wheel replicas for the Cary Graphic Arts Collection at RIT and the University of Rochester's Rossell Hope Robbins Library. The focus of this report will be on the Reading Wheel project. Further information on the project planning and execution may be found at the project website.[3]

***Figure 1**. Original test target, top left, CAD model for prototype target, bottom left, 3D printed base plate, right, for a test target production process optimization project sponsored by Image Science Associates.[4]*

In 2016, the Cary Graphic Arts Collection sponsored a Multi-disciplinary Senior Design senior capstone project to research, design, and build an 18th Century Wooden Printing Press. The press, which was built according to historically accurate designs using historically accurate materials, now resides in the Cary Library where it is used, in concert with other presses, to demonstrate historical printing processes. Building on this, the 'Ramelli's Rotating Reader' Multi-disciplinary Senior Design team was given the task of creating two replicas of the 16th Century Reading Wheel designed by Agostino Ramelli, illustrated in Figure 2.[5,6] Reading wheels were essentially rotating bookcases, which allow the user to read multiple books without needing to move, which could be particularly helpful for those suffering from gout, a form of inflammatory arthritis often affecting the joints of the big toe, making walking painful.[7] Ramelli's bookwheel design rotates books vertically around an axis, utilizing epicyclic gears to keep books at a constant angle when rotated. Ramelli designed the bookwheel as a way to easily cross reference multiple, often heavy, tomes, serving as a 16th century instantiation of having multiple browser tabs open at one time.[8,9]. The completed wheels are now interactive exhibits at RIT's Cary Graphic Arts Collection and the University of Rochester's Rossell Hope Robbins Library. The exhibits were designed by an RIT Museum Studies student with guidance from her advisor.

Methods

The Multi-disciplinary Senior Design (MSD) team projects typically span two semesters and begin with an idea and end with a product or working prototype. For the Reading Wheel project, the primary objective was to design and build replica reading wheels using primarily period-appropriate materials. The initial phase of all projects comprises problem definition and project planning. Through detailed interviews with the curators of the Cary Collection and the Robbins Library, the team developed a list of Customer Requirements (CRs) from which they developed Engineering Requirements (ERs). The main CRs given to the team were that they needed to develop a bookwheel design that (1) was historical accurate and could be built using primarily period-appropriate materials, (2) had a high level of safety for users, (3) was aesthetically pleasing to exhibit, and (4) adhered to the specified budget. The main ERs they established from these were to have an epicyclic gearing mechanism, to maintain books at reading level, and to have similar dimensions as the picture they were given as a reference, Figure 2.

***Figure 2**. Illustration of Ramelli's reading wheel (Source: Le diverse et artificiose machine del Capitano Agostino Ramelli[4])*

To make the system-level design decisions, the team used engineering tools including functional decomposition, feasibility analysis, and morphological charts. The resulting Computer-Aided Design model for the reading wheels is shown in Figure 3. To make the wood selection for the reading wheels, the team used a weighted Pugh chart approach with eleven selection criteria including factors like strength, workability and historical accuracy to determine the wood to use for the replica wheels. The results of this assessment pointed to European beech as the optimal wood choice.

With the system-level design decisions made and approved by the customers, the team began working on subsystem design and testing. They conducted extensive prototyping of the gear train and the wood finishes so that they were prepared to work with the considerably more costly European beech. Figure 4 shows the team's gear tooth profile testing apparatus. Using this, they learned that one period-appropriate gear tooth profile resulted in an unacceptably noisy gear train, particularly for library settings. Figure 5 shows samples of European beech treated with a variety of period-appropriate stains and finishes. Based on these samples, the customers selected a linseed oil finish for both the wheels and the gears. Additionally, hand-finished metal washers were used to keep the gears in place and moving freely. The only non-period appropriate material used in the construction of the final reading wheels was wood glue, which was selected because period-appropriate animal glues were not robust enough to hold up over time and were susceptible to turning rancid.

***Figure 3**. The team's CAD model of the reading wheel*

***Figure 4**. The team's prototypes of gear tooth profiles*

***Figure 5**. The team's experiment with various period-appropriate stains. From left to right: iron vinegar, iron vinegar and beeswax, linseed oil and linseed oil plus beeswax.*

***Figure 6.** Computer numerical control routing of a gear for one of the Reading Wheels*

Results

When the system and sub-system designs were complete, the wheel construction began. Using a Computer Numeric Control (CNC) machine located in the Construct maker-space at RIT, the team cut the gears and the wheel faces, Figure 6. A video of the cutting of the wheel faces, the largest objects ever cut on this machine, is available at the link in Reference 10. The team then worked with personnel in RIT's Furniture Design program in the School for American Crafts on preparing for and completing the final wood-working, Figure 7. Considerable time was invested in this process. Final assembly of the reading wheels took place in the Multi-disciplinary Senior Design Center, Figure 8. The wheels were designed so that they could easily be partially disassembled for transport. Figure 9 shows Mechanical Engineering students Ian Kurtz and Reese Salen delivering one of the replica wheels to its home at the Cary Collection at RIT. Figure 10 shows the other replica wheel in the Rossell Hope Robbins library at the University of Rochester.

***Figure 7**. The wheel face assembly took place in the Furniture Design wood shop in the School for American Crafts in the College of Art and Design at RIT*

***Figure 8**. Assembling the reading wheels*

Conclusion

Throughout the Reading Wheel project the engineering team interfaced regularly with library staff at RIT and the University of Rochester, as well as with students, faculty, and staff in the Furniture Design and Museum Studies programs at RIT. These interactions proved enriching for all involved. The MSD program provides real-world opportunities for senior engineering students including opportunities for students in technical programs to bring their skills to cultural heritage applications and environments. While not all of

these projects come to such a satisfying conclusion, most often having to do with issues of timing, these projects invariably provide an important learning experience with valuable lessons regarding the engineering process and working as part of a team to deliver a product or working prototype.

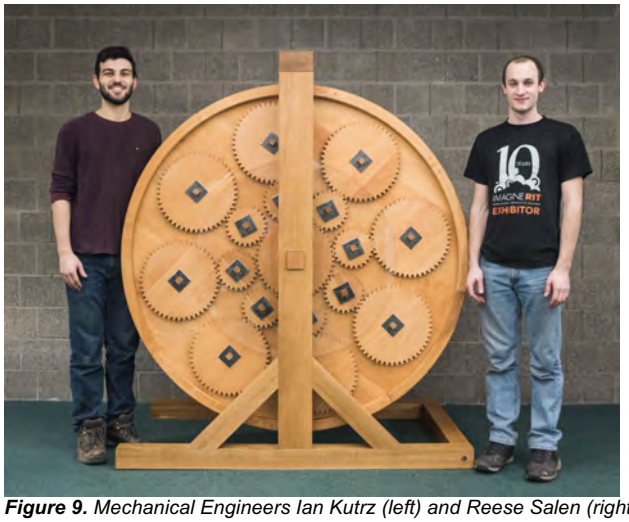

Figure 9. *Mechanical Engineers Ian Kutrz (left) and Reese Salen (right) delivering the Reading Wheel to the Cary Graphic Arts Collection at RIT.*

References

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Figure 10. *Final assembly in place at the Rossell Hope Robbins library at the University of Rochester.*

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Author Biographies

Susan Farnand is an Assistant Professor in the Program of Color Science at the Rochester Institute of Technology. Her research interests include human vision and cultural heritage imaging and reproduction. She received her BS from Cornell University and her Masters and PhD from RIT. She served as Publications Vice President of IS&T from 2013-18 and currently serves as VP.

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