
AC 2012-3022: TEACHING BIOMEDICAL ENGINEERING DESIGN PROCESS AND DEVELOPMENT TOOLS TO MANUFACTURING STUDENTS

Dr. Arif Sirinterlikci, Robert Morris University

Arif Sirinterlikci is a professor of engineering at Robert Morris University School of Engineering, Mathematics, and Science. He also serves as a Director of Engineering Laboratories as well as Co-head of the Research and Outreach Center. He has been an active member of ASEE and SME, serving as an officer of both societies and engaged in engineering education and K-12 outreach.

Teaching Biomedical Engineering Design Process and Development Tools to Manufacturing Students

Introduction

In an age where main US manufacturing sectors have been struggling and name recognition of manufacturing programs whether engineering or technology are not strong enough to attract many incoming students, the need to readjust is crucial for survival of our programs. This can easily be accomplished by identifying other fields where manufacturing is applied but not incorporated at a wider scale into our curricula. There are many areas to consider, from energy manufacturing to micro and nanotechnology. Biomedical development and manufacturing is one of these areas indicating great opportunities and future employment for our graduates and may help survival of manufacturing programs.

This study presents laboratory development efforts for a rapid prototyping and reverse engineering course taught in this ABET accredited manufacturing engineering program. The main objective of the work is to introduce biomedical design and development processes and associated tools in this manufacturing program. The driving factor is to improve the versatility of the manufacturing engineering students in addition to better marketability of the graduates in this medically oriented geographic region and beyond. The author has been developing physical and software laboratories for his biomedical engineering program. The developed laboratories are to be utilized in the design and manufacturing of biomedical devices and systems course and also included within the scope of the rapid prototyping and reverse engineering course.

Biomedical Development with Rapid Prototyping and Reverse Engineering

The efforts started with employment of rapid prototyping systems in biomodeling work for realization of 3D physical models of human anatomy based on medical imaging data. Biomodels can be employed in pre-surgical planning, educational and training purposes as well as prosthesis and implant design. Some of the students who helped developing the methodology and materials were supported by the US Department of Labor PREP program. A total of five students were involved in the original efforts, two of which were manufacturing engineering majors.

The original biomodeling work was based on Materialise's Mimics software. A series of sequential MRI (Magnetic Resonance Imaging) or CAT (Computerized Assisted Tomography) scan images are required before 3D rendering of a human anatomy element is accomplished. Figure 1 illustrates a CAT scan image of a human pelvis/hip joint in three orthogonal planes. A minimum of at least 30 slices along each plane with a slice depth of 1 to 4 mm and a medium capture resolution are needed to generate 3D bone, muscle, or organ models with clarity¹. Before the 3D rendering process takes place the slices must be put into sequence from the first one to the last in the orientation plane in question as shown in Figure 2. Once sorted, three cross-sections are produced allowing the slices to be cycled from the anterior to posterior, top to bottom as shown in Figure 1.

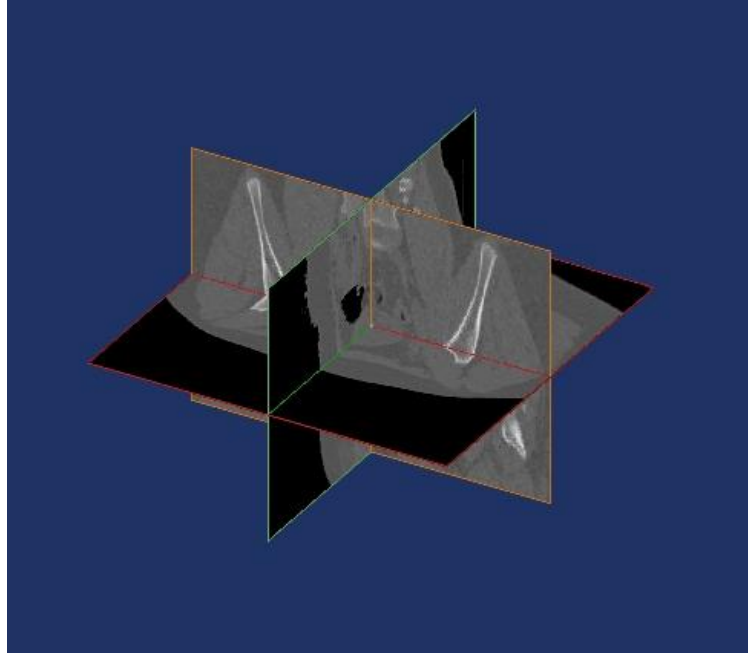


Figure 1. Compressed CAT scan model of a human pelvis/hip¹

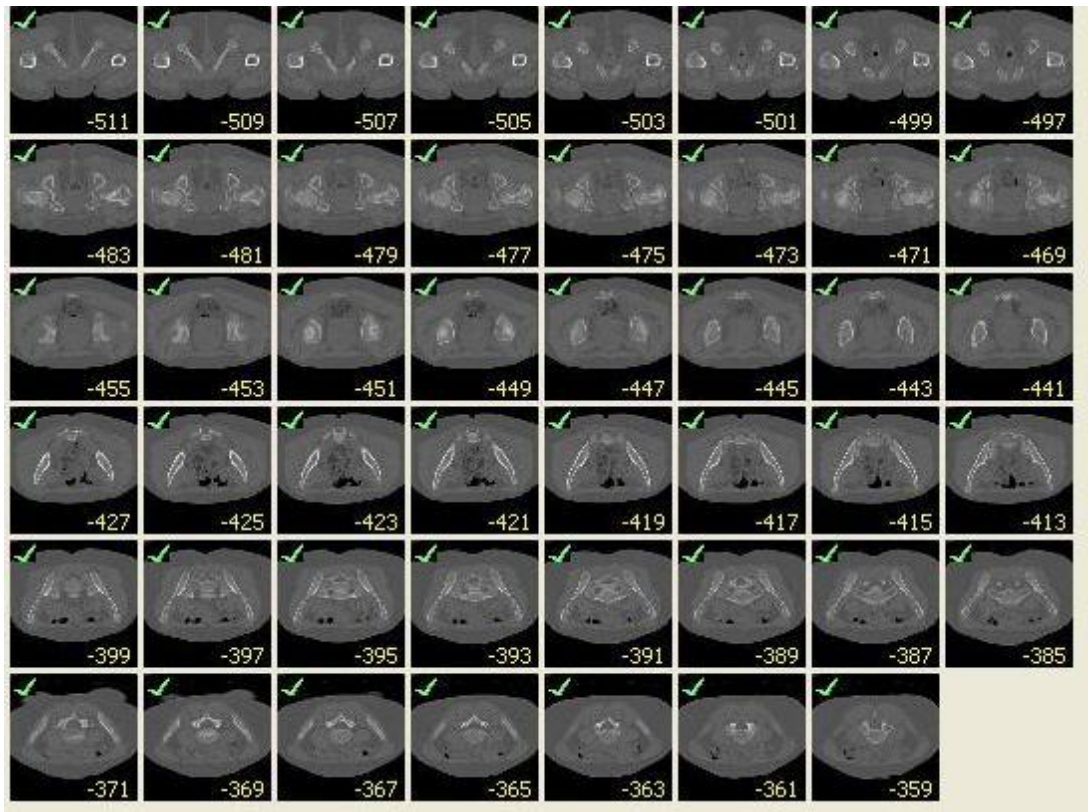


Figure 2. Sorting of individual CAT scans for an orientation plane¹

Before a 3D rendering model is generated, the users can select a certain type of tissue, hard or soft, by applying visual filters. These filters can identify the density of the tissue based on its color and shades. Each filter can be readjusted by changing its threshold value through a histogram tool. This custom threshold feature can also be used for identification of anomalies including tumors.

Figure 3 is presenting the 3D rendering process while its results are modified to show only the bone tissue model in Figure 4. Once the 3D computer model is generated, it can be saved in

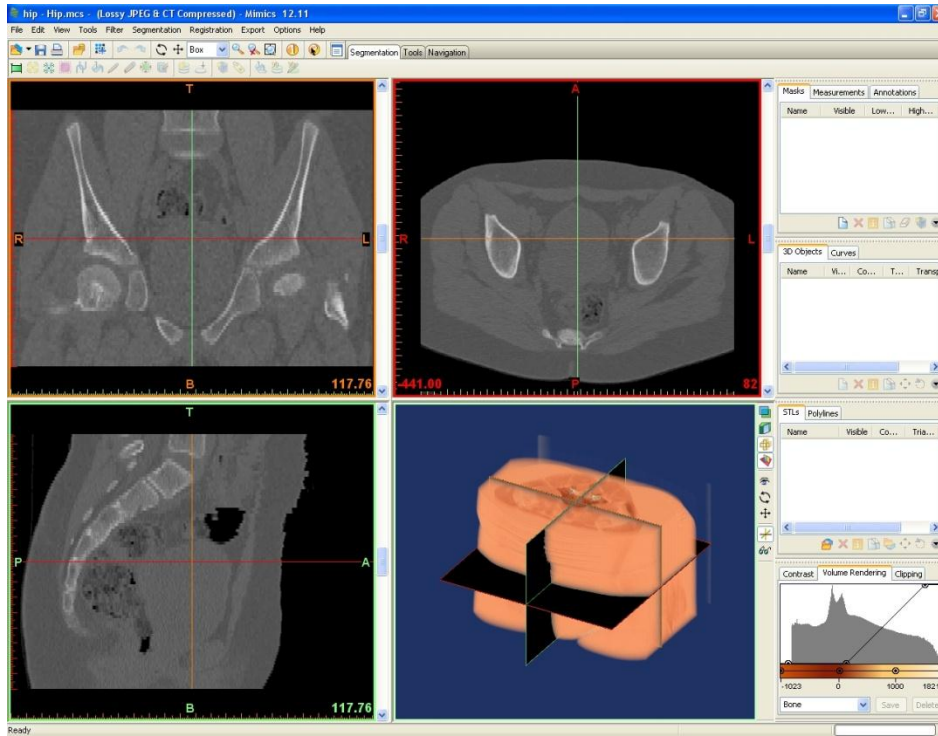


Figure 3. 3D Rendering Process¹

STL (Stereolithography) format to be printed via a rapid prototyping system. The end result of the biomodeling process is given in Figure 5 where components of the pelvis/hip model were printed separately utilizing the Dimension Elite Printer. Figure 6 also gives another example belonging to a trauma victim with missing temporal bone segment. However, skull tissue was removed from the model through software tools leaving only the soft tissue elements including skin, fat, muscle, and the cartilage.

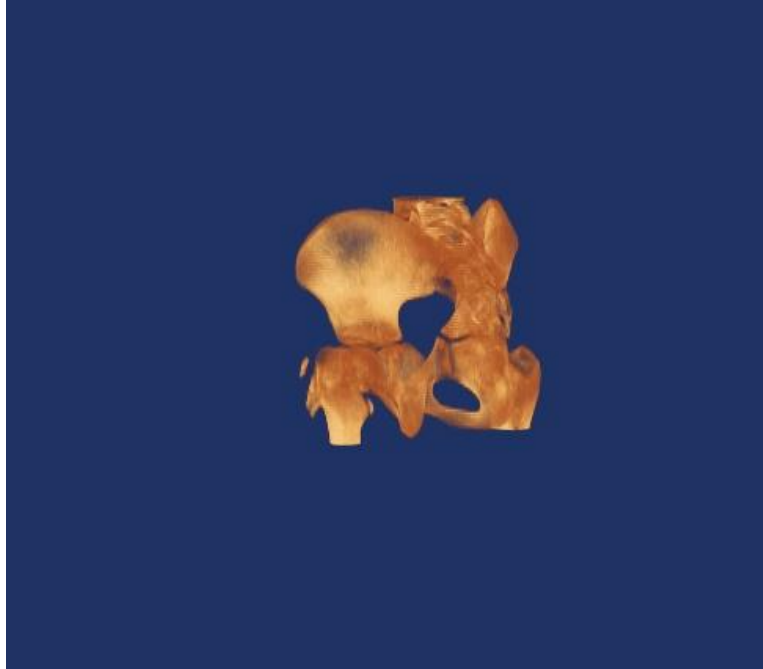


Figure 4. 3D model of the pelvis/hip scan¹



Figure 5. Physical biomodels of the pelvis/hip scan¹



Figure 6. Biomodels of a head trauma victim¹

With the completion of initial biomodeling efforts, the development team consisting the author and his students started the process of designing and developing prosthetic bones. The 3-Matic software tool was used since it interfaces well with Materialise's Mimics as a part the company's development suite. However, Geomagic Studio program was also employed as an alternative design medium for its editing features. After the 3D model is loaded into the 3-Matic program, the designers switch to the sketch mode to complete the bone model by drawing the wall structure, Figure 8. The outline of the implant is also determined by sketching as shown in Figure 9. The result is a custom fit prosthetic bone – a cranioplastic implant illustrated in Figure 10. The very next step is the generation of the replica of the physical implant by using the Dimension Elite machine. The department has the ability to print implants using biocompatible

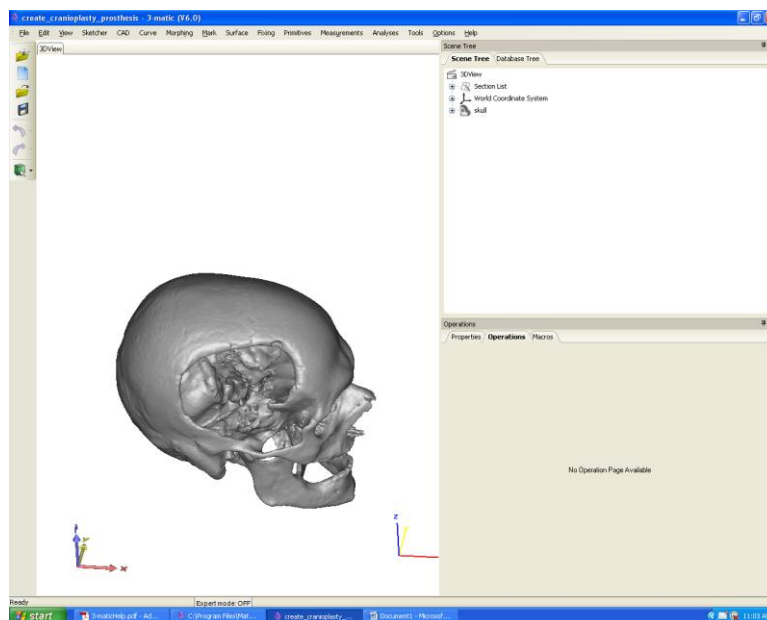


Figure 7. Materialise 3-Matic Software input²

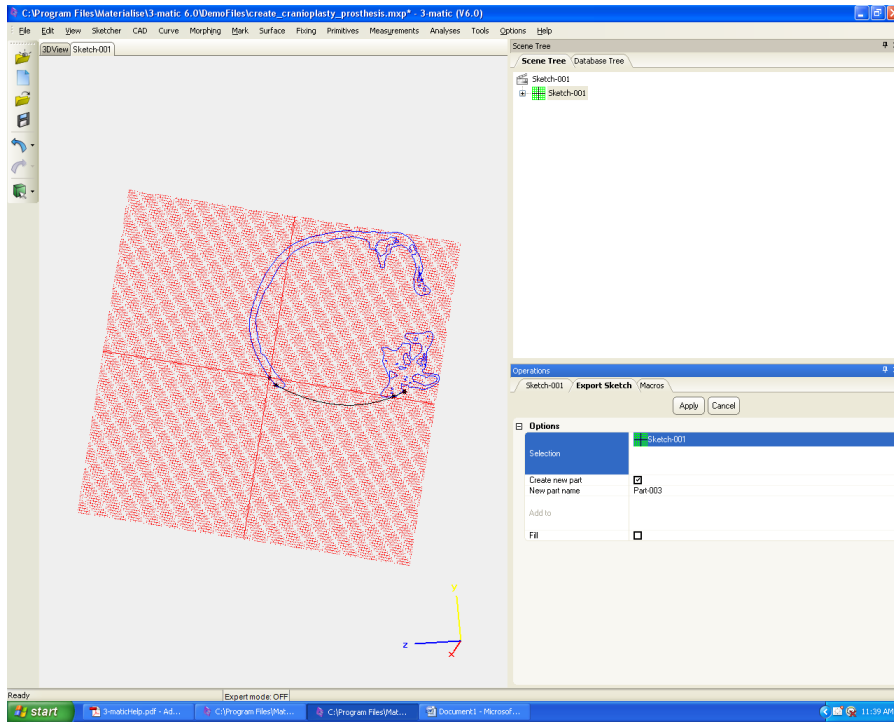


Figure 8. Sketching the prosthetic bone²

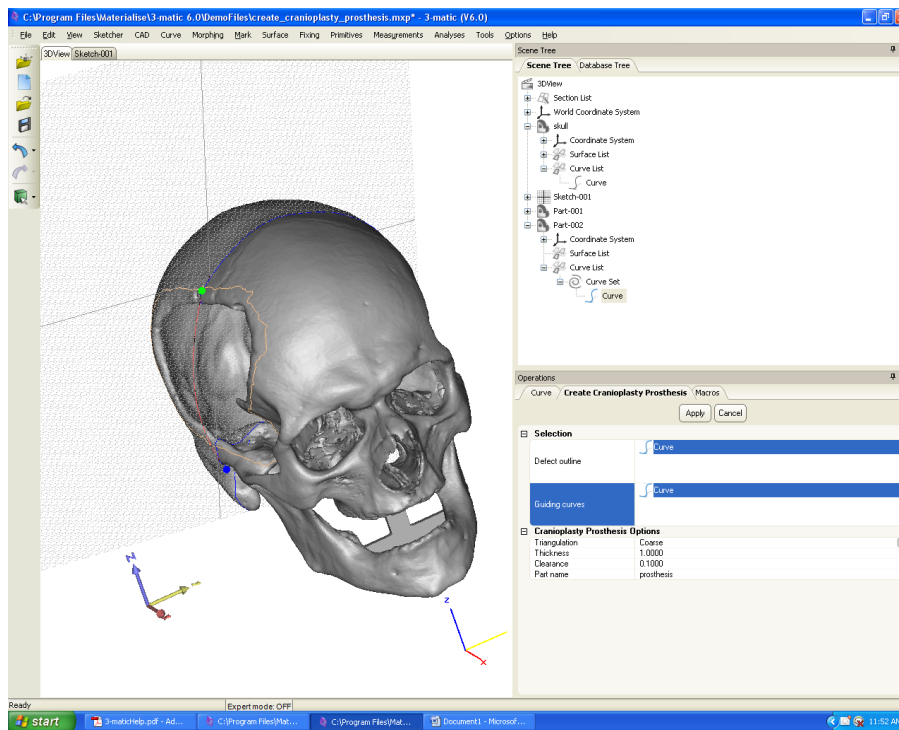


Figure 9. Outlining the prosthetic bone²

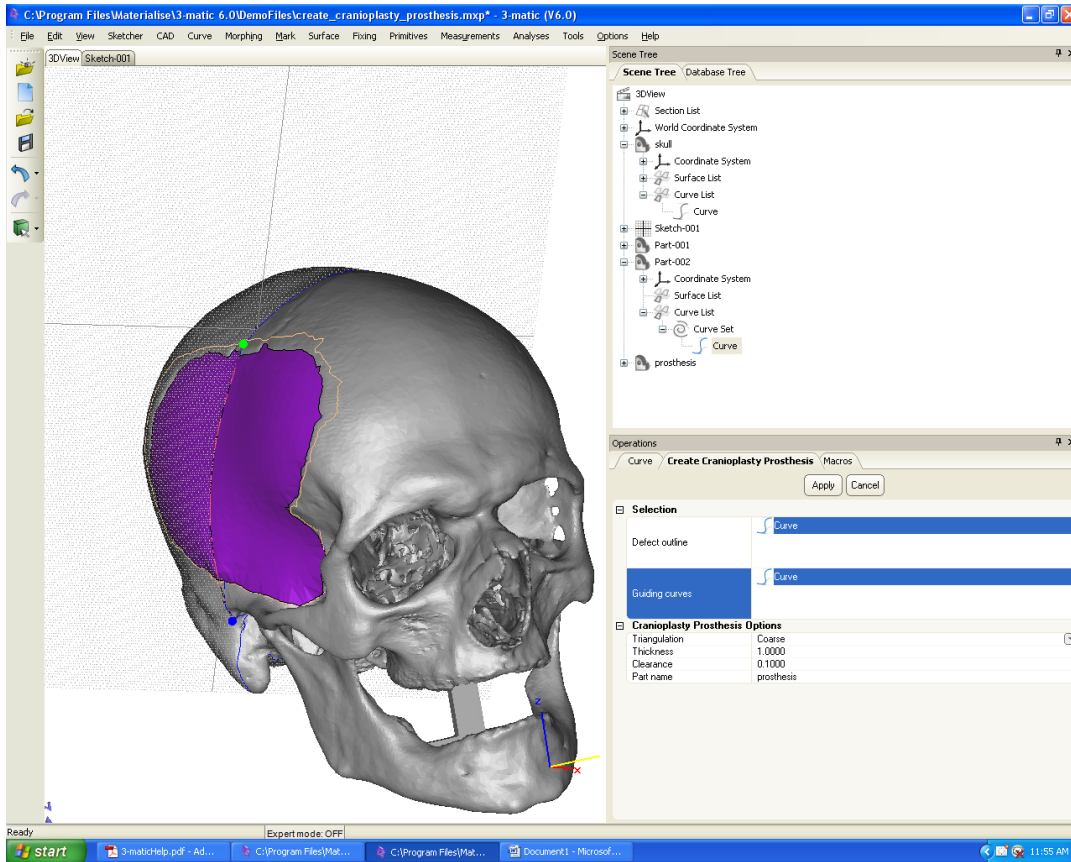


Figure 10. Custom fitted cranioplastic implant design²



Figure 11. Physical model of the skull and the custom fitted implant

materials including hydroxyapatite.

Conclusions and Future Work

The efforts will encompass introduction of biomedical engineering design and development processes to manufacturing engineering students. The initiative will not only cover generation of CAD- based anatomical and physiological data from 3D medical imaging information including CAT and MRI scans for development of bone implants, but also replacements including total knee and hip replacements. Figures 12, 13, and 14 are presenting the progress of total knee replacement project to be used with both manufacturing and biomedical curricula. The future work will also be included in a cross-listed biomedical design course and manufacturing elective for manufacturing majors in addition to the rapid prototyping and reverse engineering course.

This initiative will allow development of realistic laboratory exercises in both the manufacturing and biomedical programs. A variety of tools used in the efforts including biomedical engineering software tools such as Materialise's Mimics and 3-Matic, reverse engineering tools including FARO Arm Scanner and Geomagic Studio software as well as rapid prototyping systems including Dimension Elite will improve student preparation and boost confidence. The initiative will also increase the employability of manufacturing students by making them more versatile.



Figure 12. Scanning femur, patella, and tibia bone segments with a FARO arm



Figure 13. Scanned segment of a knee joint

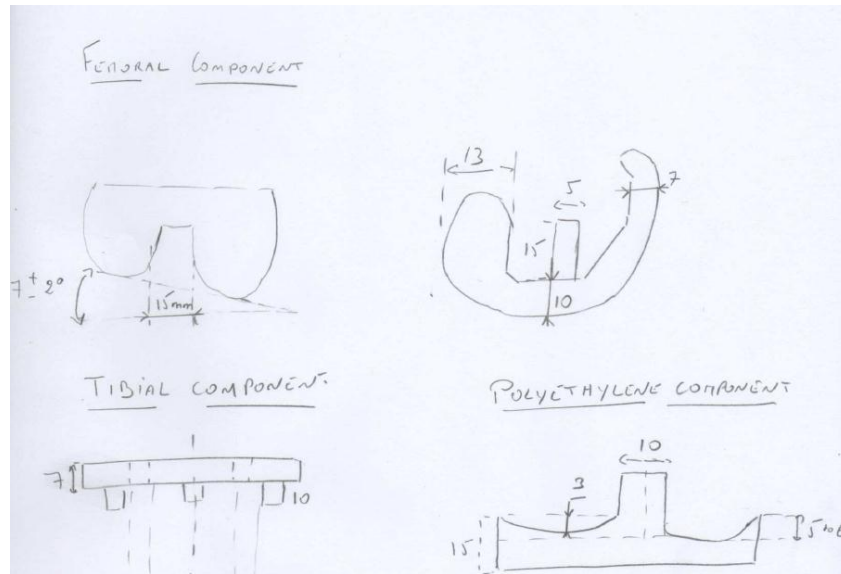


Figure 14. Student knee replacement design concept³

Even though multiple manufacturing and biomedical engineering students were involved in these development efforts and most of these tools were demonstrated in multiple courses in these programs recently, the first actual teaching of this methodology is occurring in Spring 2012 semester in the Design and Manufacturing of Biomedical Devices and Systems course and will be replicated in the Rapid Prototyping and Reverse Engineering course in Spring 2013. The weight of these new projects is 25% (1 in 4 small projects – making up for 55% of overall the grade) in the biomedical engineering course, and will be similar in nature in the manufacturing course.

In terms of the student response, it has been extremely positive with the exclusion of the past demonstrations in the small Rapid Prototyping and Reverse Engineering class of Fall 2011. The class included a non-engineering major due to being a part of our Forensics minor and a couple of mechanical majors who had to take the course, but were not as interested. Even with that, student performance was over the ABET threshold set for engineering classes at the institution (80% grade or B-) and the feedback was around or over 80% (4 out of 5) for the course evaluations.

References

- [1] Cottrell, G., Streamlining the Biomodeling Process, Unpublished Report, Robert Morris University, Moon Twp, PA, 2009.
- [2] Saltsgiver, R., Design and Development of Prosthetic Bones, Unpublished Report, Robert Morris University, Moon Twp, PA, 2011.
- [3] Lesciux, L., Design and Development of Total Knee Replacements, Unpublished Report, Robert Morris University, Moon Twp, PA, 2010.