AC 2007-604: DEVELOPING GENERIC PROCEDURES OF CREATING ARCHITECTURAL COMPONENTS FOR 3-D AUTOCAD COURSE

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Abstract

Although there are plenty of AutoCAD books available for architects, interior designers, and engineers, it has been difficult for the author to find an appropriate textbook for students who major in interior design while teaching AutoCAD, especially 3-D AutoCAD at the sophomore level. Most existing 3-D AutoCAD textbooks are more engineering oriented. Industrial machine components such as bolts and nuts are commonly used as tutorial examples. The author also found that existing 3-D AutoCAD textbooks are lack of art and design subjects particularly subject matters of interior design and visual presentations. Therefore, it is necessary to develop course materials and to create tutorial examples that are relevant to interior design and architectural design with graphic images. Currently, limited generic procedures were found in the textbook to guide students to create 3-D architectural components and interior space models with 3-D AutoCAD. Therefore, creating appropriate tutorial examples is becoming more crucial in course materials. This article presents the tutorial examples and case studies with images in the newly developed course material, as well as how those 3-D examples and case studies were created.

The author received a faculty research grant during summer 2006 to explore innovative design methods by using 3-D AutoCAD to achieve form transformation and space interlocking in design process. The goal of this research project is aimed specifically at the task of developing generic procedures for creating architectural components by using Boolean operations. This newly developed course material will be used in AutoCAD courses especially for 3-D AutoCAD. It provides students with more systematic and comprehensive tutorials and case studies. The author integrated two case studies of reconstruction of the masterpiece architecture in this course material because it is a research topic that many researchers and scholars are exploring. It provides the three-dimensional visualizations for these scholars to explore the hidden treasures in the past and to get inspirations for today's design. These two case studies also presented typical architectural components, such as, triangular pediments, domes and barrel vaults in the application of Boolean operations in 3-D AutoCAD. The significance of this newly developed course material is that it provides more relevant interior design and architectural design tutorials and case studies with generic procedures, as well as visual presentations.

Objectives of Course Materials

The first objective of this AutoCAD course is for students to learn both surface modeling and solid modeling methods. Since Boolean operations are powerful features of AutoCAD to generate more complex forms, the second objective is to effectively demonstrate how to use Boolean operations and in the mean time to inspire students design creativities. Another objective of this course is to present procedures of creating architectural components as comprehensively as possible because most of AutoCAD textbooks are using interior design unrelated components as examples.

The author has explored the hybrid digital method of reconstruction of the masterpieces of architecture with geometry analysis. Geometric form transformation with Boolean operations was also explored in funded summer research. The generic procedures of using Boolean Operations to create 3-D models by using AutoCAD were developed. This includes creating typical architectural components, such as columns, domes, triangular pediments, and intersected barrel vaults. 3-D models of the Florence Cathedral and the Baths of Caracalla were created by the application of the generic procedures. A number of 3-D models were created to reflect these applications. 3-D models of a modern architecture designed by Frank Lloyd Wright, the Falling Water House and the Cooper Residence designed by Gwathmey-Siegel, were created by applying the new procedures.

Tutorial Examples and Case Studies

In the course material there are two tutorials. One is for surface modeling and the other is for solid modeling. These two tutorials are designed for students to have a continued tutorial intentionally. Students have the flexibilities of saving the drawings, reopening the drawings, and continuing working on the drawings. The tutorials provide students with step-by-step procedures and instructions. Basic commands and procedures are demonstrated in these two tutorials.

In addition to these two tutorials, four case studies were incorporated into the course material. Famous great buildings or masterpieces are chosen for these case studies. These case studies are 3-D model of reconstructions of the past – Baths of Caracals; 3-D model of Florence Cathedral, which was created by digital method with geometry analysis, especially the application of Golden Ratio; 3-D model of Falling Water house designed by Frank Lloyd Wright, which is the application of solid modeling with Boolean Operations, and digitized materials application. The last one is a 3-D model of Cooper Residence designed by Gwathmey-Siegel, which focused on solid editing command and procedures. The following sections in this paper describe two main tutorials and four case studies.

Tutorial One –Surface Modeling – Beach House

The following images represent the first tutorial in course material – Beach House (Figure 1 – Figure 3). This tutorial focuses on surface modeling, which includes all major commands such as TABSURF, RULSURF, EDGESURF and so on.

Figure 1: 3-D Model of Beach House
(Support was provided by Purdue Research Foundation)

Figure 2: 3-D Model of Beach House Interior View
(Support was provided by Purdue Research Foundation)

Figure 3: 3-D Model of Beach House Interior View
(Support was provided by Purdue Research Foundation)

It is obvious to see from the images above that the furniture and accessories were chosen for the demonstration of specific command. For example, lighting fixtures on the ceiling were created by using EDGESURF command; the decorative curved glass panel on the wall was created by using TABSURF command; the round table was created by using RULSURFE command. Other furniture and caseworks were created by using surface modeling command. The only solid modeling command that used in this tutorial is BOX command for creating sofa because the FILLET command was used for creating rounded edge for sofas. The FILET command only can be used on solid models. After completing this tutorial, students will be able to master all different surface-modeling commands. The reason of introducing surface modeling is that it takes less memory than solid modeling, and surface modeling command can create special 3D models, such as mesh surface objects that solid modeling method can not. For example, EDGESURF command can create 3D model of lighting fixture, which cannot be created by solid modeling command in tutorial one. Therefore, surface modeling should be introduced because of its special functions. Another demonstration project used in this course material is to create table lamps. All the lampshades were created by using RULSURFE command (Figure 4).

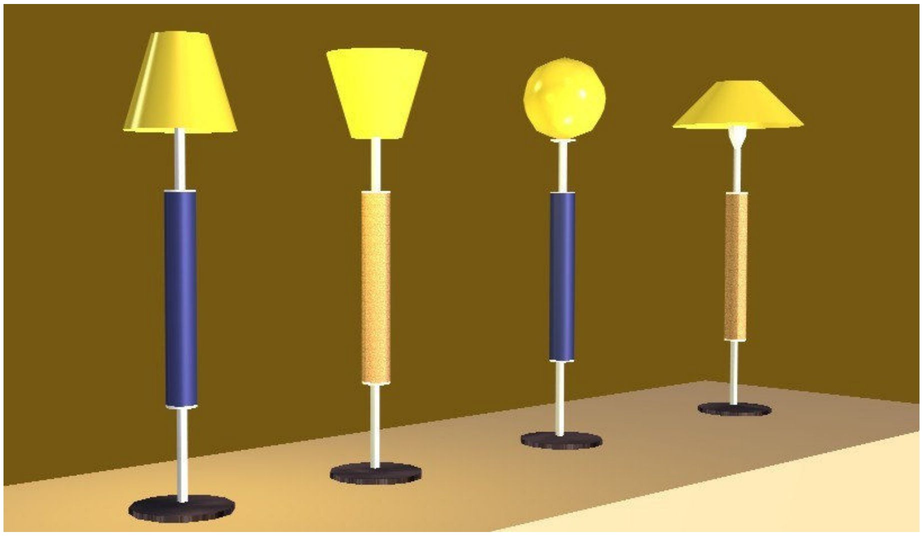

Figure 4: 3-D Model of Table Lamps
(Support was provided by Purdue Research Foundation)

Tutorial Two –Solid Modeling – Gallery Lobby

The second tutorial in the course material is a Gallery Lobby. It provides step-by-step procedures of solid modeling process. All the solid modeling commands are demonstrated during the process of tutorial. The following images represent the 3-D model of Gallery Lobby (Figure 5 – Figure 8). The powerful solid modeling features, such as REVOLVE, EXTRUDE and Boolean Operations were demonstrated in the tutorial. For example, columns were created by using REVOLVE command; the curved loft was created with EXTRUDE command; the picture frames were created with serious of Boolean operations. In addition to these commands, lighting design and mapped material applications were demonstrated in the tutorial.

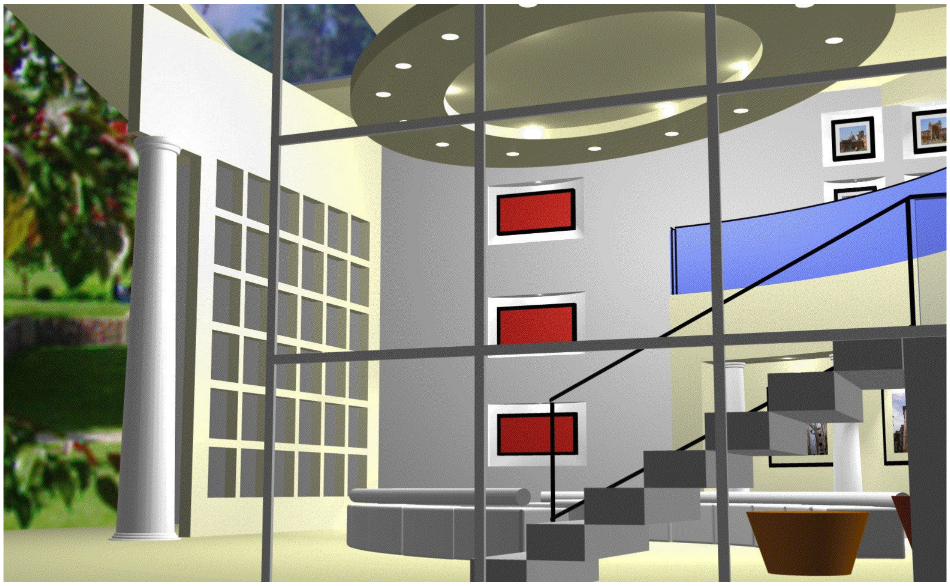

Figure 5: 3-D Model of Gallery Lobby Interior View
(Support was provided by Purdue Research Foundation)

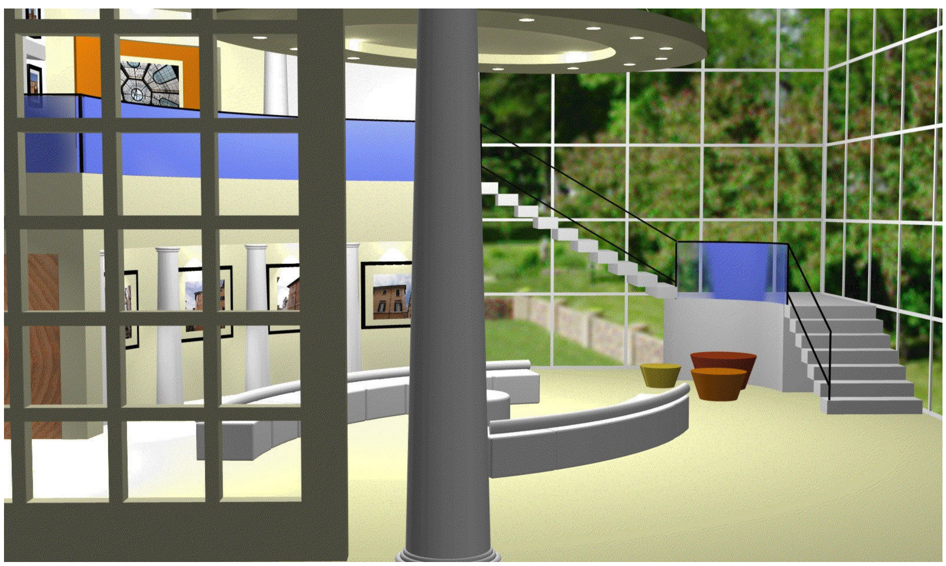

Figure 6: 3-D Model of Gallery Lobby Interior View
(Support was provided by Purdue Research Foundation)

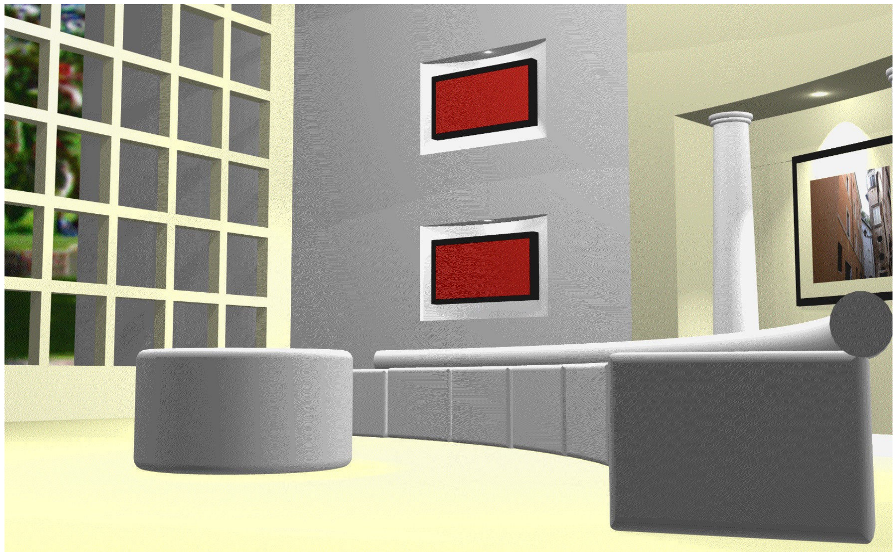

Figure 7: 3-D Model of Gallery Lobby Interior View
(Support was provided by Purdue Research Foundation)

Figure 8: 3-D Model of Gallery Lobby Interior View
(Support was provided by Purdue Research Foundation)

Case Study One – Baths of Caracalla

The first case study is the digital model of Baths of Caracalla (Figure 9 and Figure 10). In this case study, not only typical architectural components, such as column, triangular pediment and arch window were demonstrated by using solid modeling and Boolean operations, but authentic Roman architectural materials application has also been demonstrated. A generic procedure for reconstruction of ancient ruins and historical buildings were outlined in course material.

Figure 9: 3-D Model Perspective of Baths of Caracalla
(Support was provided by Purdue Research Foundation)

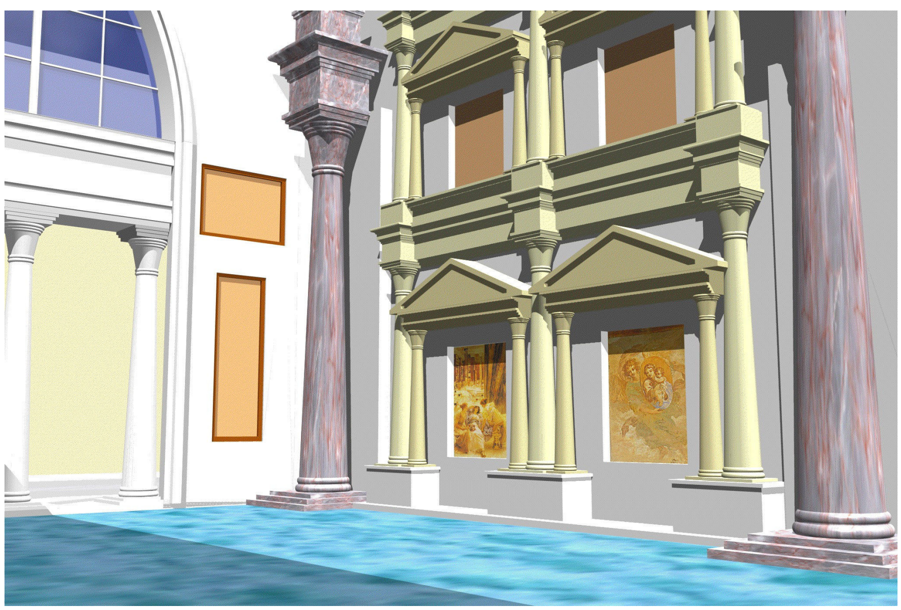

Figure 10: 3-D Model of Baths of Caracalla with Authentic Material
(Support was provided by Purdue Research Foundation)

Case Study Two – Florence Cathedral

The second case study is to create a 3-D model of Florence Cathedral. In this case study, barrel vaults and dome were demonstrated with solid modeling and Boolean operations. In addition to that, a digital method along with Golden Ratio analysis was used in the data collection process. The following images represent the 3-D model of exterior and interior view of Florence Cathedral. SLICE command was demonstrated in the case study. Figure 12 represent intersected barrel vaults inside Florence Cathedral.

Figure 11: 3-D Model of Interior View of Florence Cathedral
(Support was provided by Purdue Research Foundation)

Figure 12: 3-D Model of Interior View of Florence Cathedral with Barrel Vaults
(Support was provided by Purdue Research Foundation)

A generic procedure of reconstruction of the past was developed. The following is the digital generic procedure of reconstruction of the masterpiece of architecture with geometry analysis especially Golden Ratio analysis:

1. Data collection and literature review – This is the first step for creating 3-D models. It includes field measurement and photo taking. However, it is unrealistic for everyone to have the opportunity to physically go to the field for data collection. The literature review becomes crucial to find relevant information as much as possible. The Internet is a very useful source. Extensive amount of existing literature and photos can be found from the Internet. One recommendation for this step is that even though field measurements and photos were taken, it is still essential to do the literature review. The more information about the building or site, the smoother process of creating the models will be. The second recommendation for literature review is to try to find floor plans and elevations with graphic scales. This allows you to enlarge or reduce the drawings as necessary without distorting the dimensions. Dimensions are critical for creating a more accurate 3-D model. Therefore, to obtaining sufficient and accurate dimensions becomes a key for a successful reconstruction process.

2. Computational geometry analysis on floor plans and elevations – this step serves as verifications for uncertain data such as dimensions and missing portions of the structure. The geometry analysis also can be used as rationales for completion of floor plans and elevations when some of structures were missing. A floor plan or elevation that is retrieved from the Internet or obtained from a book usually will not have all the dimensions. It is necessary to use computational geometry method to calculate unknown dimensions. As long as the drawings are presented with graphic scale, it is not difficult to discover all the dimensions. The following is an example of computational geometric analysis for Florence Cathedral. Figure 13 is the floor plan and Figure 14 is the cross section of the cathedral. Literature review shows that squares and rectangular were used extensively in Roman geometric construction [2]. Circles on the floor plan and section indicate that the shapes inside circles are squares. It is obvious that many spaces were constructed followed the rule of height equals side length. If one side of the dimension is known, then the height will be found easily. The other characteristic of Roman architecture is the constant use of rectangle. By using Golden Ratio or Golden Section, it is not hard to calculate the height of rectangular in Section of Cathedral (Figure 14). The golden ratio can be described as if one divides a line into two unequal segments so that the ratio of the first short segment to the long segment equals to the ratio of the long segment to the total line length (the short segment plus the long segment) [1]. To apply Golden Section in this case in Figure 7, A is a longer segment and B is a shorter segment. The formula used for calculation the value for B is:

   $$B : A = A : (A+B)$$

   'A' can be found from the floor plan with graphic scale. It is also the height for that square. Value of variable 'B' is the height of the rectangular, which is unknown. The value of variable 'C'can be found from the floor plan and C equals to A + B. With a simple mathematic calculation, it is easy to find out the value for B, which is about 3'-10". The other way can be used is to use the irrational number 0.618 along with the formula $B: A = 0.618$ to calculate the B value. Same process can be done on cathedral floor plan to calculate the value for variable D. The formula for variable D is $D: A = A : (A + D)$. The third characteristic in Roman architecture geometric construction is symmetry [3]. Because of this, it makes calculation and modeling process much easier and quicker. In Figure 14 of the section of the cathedral, portions on the right side are missing. But with the mathematical computation and Golden Section theory, it is not difficult to figure out all the dimensions and reveal missing structure portions.

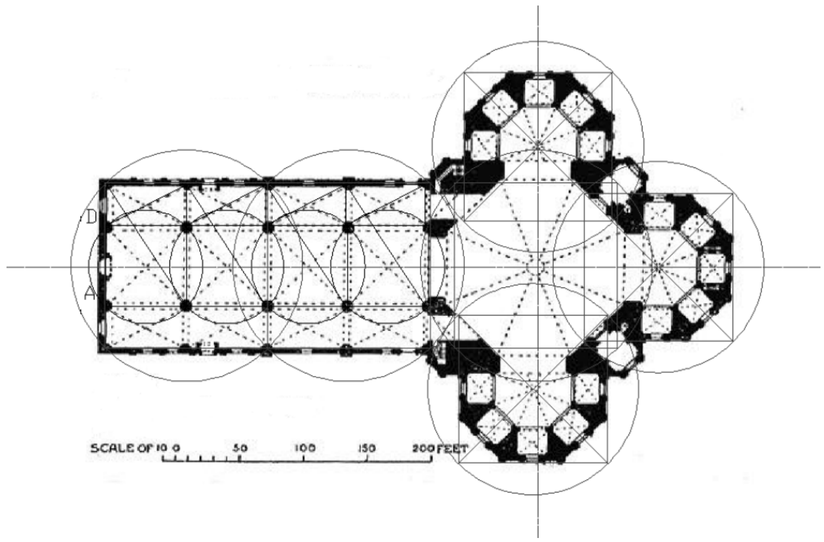

Figure 13: Florence Cathedral Floor Plan

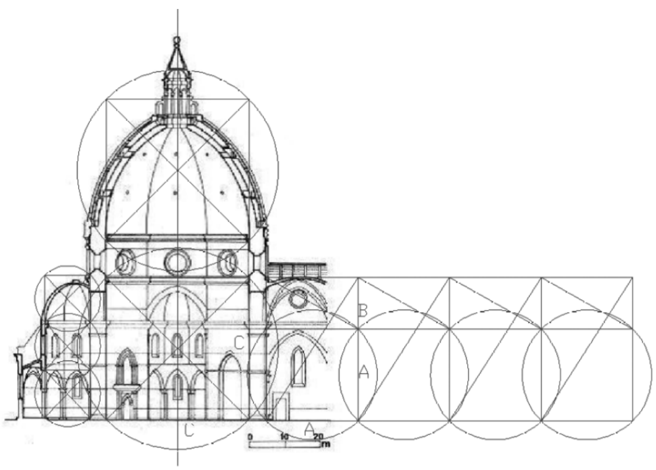

Figure 14: Florence Cathedral Cross-section

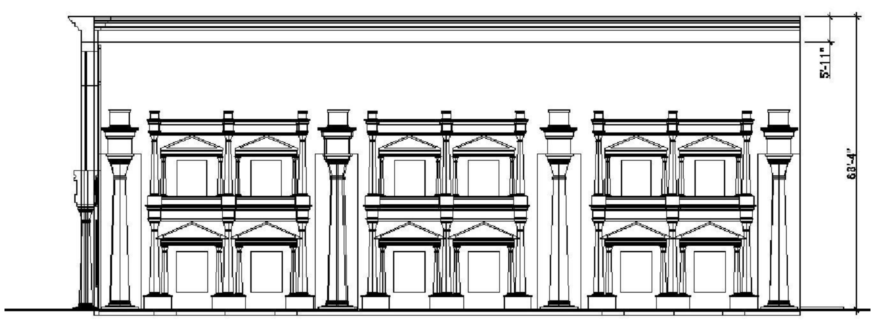

Figure 15: Elevation of Baths of Caracalla

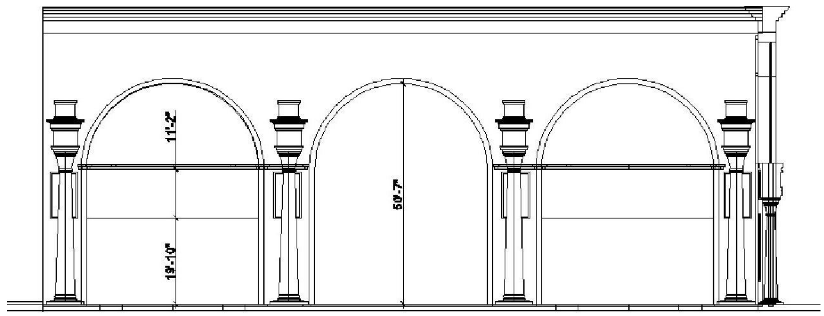

Figure 16: Elevation of Baths of Caracalla

Figure 15 and Figure 16 represent the elevations of Baths of Caracalla. It is obvious that the building structure is symmetrical with repetitive geometric forms, symmetrical floor plans and elevations. These architectural characteristics make the model building process simpler. During the process, two major architectural components were created. They are the column and the triangular pediment. By using the theory of geometry *symmetrical relationships*, which means *the same proportions*, rather than some kind of mirror symmetry [4], it is easy to create the 3-D model of triangular pediments with different scales shown in Figure 15. You may just create one column and one triangular pediment and use SCALE command to create the 3-D models with different scale. The digital model looks complex, but the process is very simple.

3. Construction of digital 3-D models using Boolean operations – after all the dimensions are obtained and verified with computational geometry analysis, it is the time to start building the digital model. The final perspective views of digital model look complex and hard to build. However, both Baths of Caracalla and Florence Cathedral are symmetrical and most of architectural components are exact the same or with a smaller scale. One must to create one model for that component and copy it over for the rest exact same components. The following describes the procedure and commands used to create the digital model. The digital method is 3-D AutoCAD with Boolean operations. The process is to create each individual architectural piece first and then put them together.

4. Digitizing authentic architectural materials and importing them into the materials library – after finishing the 3-D model, the next step is to apply authentic materials to the digital model. Photos from field or Internet or scanned documents from books can be modified and edited by Photoshop or Photo Editor software. When the photo image is not completed or needs some modifications, for example, the fresco of Baths of Caracalla is not a completed image and some portions were missing, using Photoshop can modify the image to recover its complete image. The images of the stained glass in Florence Cathedral, as another example were retrieved from the Internet and modified by Photoshop. When the image is ready, you can import the images to the materials library, and then modify the materials by adjusting the bitmap.

5. Applying authentic materials and lightings to the 3-D models and create perspective views – this is the last step and it is as straightforward as standard process. One recommendation for this is to use distance lighting to simulate the sunlight for exterior models because shadows will create dynamic effects for the images.

Case Study Three – Falling Water House Designed by Frank Llyod Wright

In this case study, solid modeling commands were demonstrated extensively (Figure 17 and Figure 18). Authentic material application was also demonstrated. The key point for this case study is to set up the right elevations in the model building process. This case study is a good example of using 3-D AutoCAD with Boolean operations to create a 3-D model of modern architecture. In addition to demonstrate solid modeling, sun light simulation is also applied in this case study. To present architectural model with realistic lighting, sun lighting simulation must be used. In the previous tutorial and case study, only spot light and point lightings were demonstrated. In this case, sun light simulation was demonstrated properly. Students learned how to specify an accurate geographical location and time when the sun is simulated.

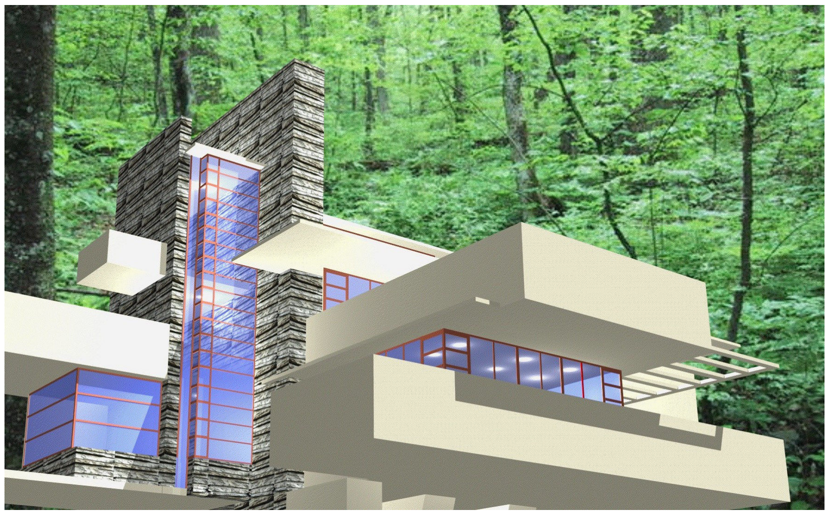

Figure 17: 3-D Model of Falling Water House Designed by Frank Lloyd Wright
(Support was provided by Purdue Research Foundation)

Figure 18: 3-D Model of Falling Water House Designed by Frank Lloyd Wright
(Support was provided by Purdue Research Foundation)

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Case Study Four - Cooper Residence designed by Gwathmey-Siegel

The last case study is to create a 3-D model of Cooper Residence designed by Gwathmey-Siegel (Figure 19 and Figure 20). The following two images are the exterior views of Cooper Residence. In this case study, solid editing commands were demonstrated. It also demonstrated form transformation with Boolean operations. Simple geometry forms, such as cube and cylinder are used to accomplish the form transformations. The different approach in this case study is that artificial looking landscape was created. Instead of using landscaping library associated with AutoCAD or use imported imported images, simple and artificial looking landscaping were created and utilized in this case study.

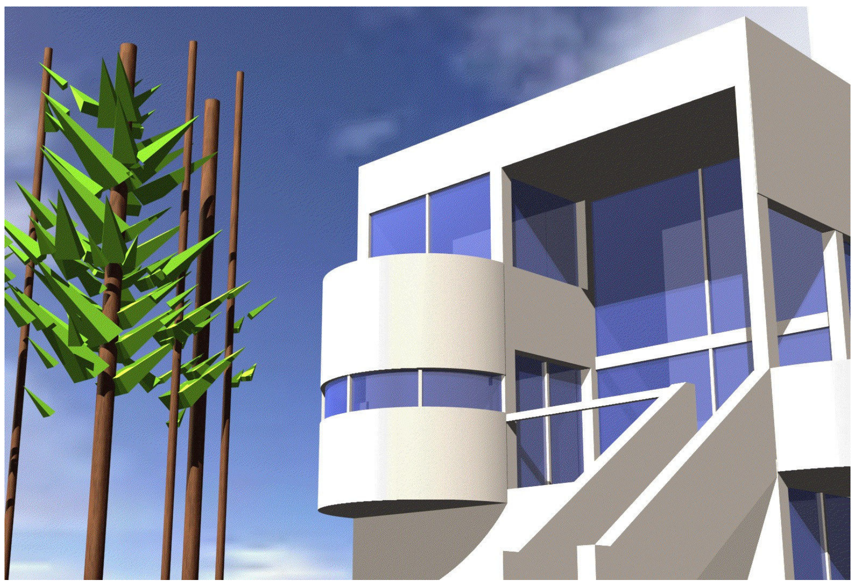

Figure 19: 3-D Model of Cooper Residence designed by Gwathmey-Siegel
(Support was provided by Purdue Research Foundation)

Figure 20: 3-D Model of Cooper Residence designed by Gwathmey-Siegel
(Support was provided by Purdue Research Foundation)

Conclusion and Discussion

In fall semester 2006, the author used this course material when teaching AutoCAD course. The rendering images were shown to the class; the tutorials were demonstrated when surface modeling and solid modeling were introduced. In-class exercises were given to students to reinforce the new concepts. Two project assignments were given to students. One was focused on surface modeling and the other one was focused on solid modeling. The surface-modeling project is to design a conference room, and the solid modeling project is to design a gallery lobby. The author is very pleased with students work. Compared with the student projects from the last year, this years' students' work are more advanced and well designed.

A course assessment and class evaluation was conducted. Many positive feedbacks were received from students. At the beginning of the class, a tutorial manual written by the author was distributed to each student. Compare with the course evaluations from the last year, this year's students' evaluation regarding course materials and textbook is much better. Students stated that the textbook is boring because nuts and bolts were used as the demonstration in the textbook in last year's evaluation. But in this year's evaluation, students stated that they love the course material and it is fun to learn 3-D AutoCAD. Students enjoyed the whole learning process and they are pleased and satisfied with their work. Students also stated that they have systematic procedures to follow for this class and it makes the learning process much easier. Students found much more enjoyment in the class and learned a great deal from this course. Some students also indicated in the course evaluation that they would love to have a new textbook written by the author. It is obvious that a new textbook is needed when teaching AutoCAD for interior design major students.

It is true that many other 3-D software are available out there for creating three dimensional models, such as 3-D Studio, Form Z and Chief architect. However, AutoCAD can be taught as a fundamental skill. Students can learn how to use other software when it is necessary. AutoCAD also has the function of inserting files from 3-D Studio [5]. Maya from Autodesk is powerful 3-D software. Maya's powerful suite of animation tools makes it easy for users to produce animations for design reviews and client presentations. Maya allows users to importing CAD data, such as dwg/DXF files to create dramatic photo real images, animations and effects for print, web, multimedia and television commercial. Therefore, learning 3-D AutoCAD is essential. It will prepare students ready for their advanced learning and professional practice.

Acknowledgement

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