Desktop and Augmented VR for Delivering Materials for Graphics Modeling and Animation Courses

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(Work-in-Progress) Prototype Desktop and Augmented VR for Delivering Materials for Graphics Modeling and Animation courses

This paper explains the design of a prototype desktop and augmented Virtual Reality (VR) framework as a medium to deliver instructional materials to the students in an introductory computer animation course. This framework was developed as part of a Teaching Innovation Grant to propose a cost-effective and innovative instructional frameworks to engage and stimulate students. Desktop-based virtual reality presents a 3-dimensional (3D) world using the display of a standard desktop computer available in most of the PC labs on campus. This is a required course at this university that has students not only from the primary department, but from other colleges/departments as well. Desktop VR has been chosen as a medium for this study due to the ease-of-access and affordability; this framework can be visualized and accessed with the available computers in PC labs available in university campuses. The proposed research is intended to serve as a low-cost framework that can be accessed by all students. The concepts of 'computer graphics, modeling & animation', instead of being presented using conventional methods such as notes or power point presentations, are presented in an interactive manner on a desktop display. This framework allows the users to interact with the objects on the display not only via the standard mouse and keyboard, but also using multiple forms of HCI such as Touchscreen, Touchpad, and 3D Mouse. Hence, the modules were developed from scratch for access via regular desktop PCs. Such a framework helps effective pedagogical strategies such as active learning (AL) and project-based learning (PBL), which are especially relevant to a highly lab-oriented course such as this course titled 'Introduction to Animation'. Finally, the framework has also been tested on a range of VR media to check its accessibility. On the whole, this proposed framework can be used to not only teach basic modeling and animation concepts such as spatial coordinates, coordinate systems, transformation, and parametric curves, but it is also used to teach basic graphics programming concepts. Hence, instead of a touchscreen, the modules have to be developed from scratch for access via regular desktop PCs. Such a framework helps effective pedagogical strategies such as active learning (AL) and project-based learning (PBL), which are especially relevant to a highly lab-oriented course such as this animation course.

Introduction and Background

In today's higher educational institutions, classrooms are often plagued by challenges including lact of motivation and diminishing attention span, which may result from classroom practices that fail to address the cognitive overload, especially when teaching new information. Captivating students' attention entails involving the participant (student) in the learning process and VR is a proven tool that can engage learners effectively (Toth, Ludvico, & Morrow, 2014, Chandramouli, Zahraee, & Winer, 2014, Jin & Nakayama, 2013, Jen, Taha, & Vui, 2008, Karweit, 2002). According to Sherman and Craig (2003), VR can be described as "... a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation." From the earlier discussion, it is quite obvious that VR tools serve as a viable alternative offering a cost and material-efficient solution by replacing the need for actual physical materials, which is especially important in case of CG materials because of the creative components involving storyboarding and production pipeline.

3D modeling and animation courses are not only pursued by students in computer graphics (CG) and related disciplines, but also from other areas such as mechanical engineering/technology, civil engineering/technology, and several other departments as well. Even though numerous new software tools including proprietary commercial software Open Source software are available, a proper knowledge of the basic concepts of 3d modeling and animation is irreplaceable and inevitable in order to create useful 3D visual models and animations. Despite the opportunities available for students in the area of 3D modeling and animation, it is indeed a challenge to properly equip students to take advantage of these opportunities. One of the important problems that needs to be addressed in this area is the over-reliance on software tools and not giving proper importance to the concepts of computer graphics.

However, faced with dwindling attention-span and the urge to see results immediately, it is quite challenging to engage all students to spend the required amount of time to master the CG concepts. In Computer Graphics Technology (CGT), while the predominantly visual nature of the courses has several inherent advantages, there are disadvantages as well. Often times, it is challenging for students to patiently wait to learn the underlying basics before seeing the end result. Especially, with the availability of software applications that can swiftly create 3D objects and cool software gizmos, it is hard for young minds to resist the temptation to explore a lot at once. However, succeeding in the CGT program as well as in their careers requires a firm grasp of the fundamentals of the production pipeline and the processes therein. To overcome this challenge, it is important to balance courses with activities to allow latitude for their creativity whilst boosting critical-thinking and problem-solving skills. The lab assignments typically include a part where they should summarize their understanding of the theory materials but also includes a creative part where they choose a theme of their own choice to demonstrate their graphics skillsets. A strong understanding of the fundamental mathematical, geometric, trigonometric, and physics fundamentals plays a crucial role in determining the career-success of computer graphics (CG) students. Students, especially those at the beginner's level, typically tend to associate theoretical knowledge with 'textual information' involving substantial reading. Hence, this effort puts forth a novel PBL-based approach wherein an interactive portable desktop Virtual (dVR) framework is used to methodically organize and present such foundational information. The framework uses a sequential learning process, beginning with simple concepts, gradually advancing towards more complex ideas. As the medium used is desktop VR, the computers in the labs in our campus can be used ‘as is’. An Open Source plug-in can be used on the standard browsers such as Internet Explorer and Mozilla Firefox to view and interact with the virtual worlds.

VR as an Instructional Training Tool for Computer Graphics

Virtual reality (VR) and computer graphics (CG) are highly interrelated. The evolution of VR has been aided by the advancements in 3D graphics, visualization, and interactive user interfaces. Evidently, CG has tools and techniques tremendously influence and impact the capabilities of VR and also considerably define the limitations as well. However, in this study, multiple modes are used to overcome space and cost limitations.

Figure 1: Multiple VR-based modes of Interaction; Clockwise from top-left
Using Head Mounted Displays, Using Controllers on Desktop, Using Touchpad, Stylus

One of the most important advantages of using VR is the ability to engage students to facilitate active learning and problem-based learning. Active learning and project-based learning are proven tools to facilitate learning and retention (Prince & Felder, 2000, Hadim & Esche, 2002, Mills & Treagust, 2003) as they can motivate students and also facilitate applying the knowledge and skills gained in the classroom in the workplace. Pedagogical practices such as Active Learning (AL) and Project-Based Learning (PBL) involve a higher level of interaction thus promoting interest in the training/learning process. Also, virtual environments help avoid cognitive overload and facilitate relating novel information learned to current knowledge. Especially, the the modules are designed to be accessible via multiple modes design will allow customization for access via desktop VR (dVR) and augmented VR (aVR).

Using the proposed framework

1. The weekly theory lessons, instead of being presented primarily in the textual format or as PDF or Power Point files, are presented via the interactive browser interface.
2. The modules will introduce the computer animation concepts in an interactive manner to the students. The interactivity of the interface reduces the cognitive load and students can repeat a chapter until they are completely thorough. Then they will be led to another screen that presents the students with questions (in the form of visual demonstrations) to help them review the learning.
3. Next, the students will be led to the subsequent chapter. The modules will be divided into conceptual categories such as mathematical concepts, physics concepts, trigonometric concepts that help them to access them as a reference if there is a need.

Methodology

The VR-based framework design from a computer graphics perspective include the following:

- A VR laboratory capable of delivering conceptual (theoretical) and practical CG training
- Extensible VR modules designed to support immersion, navigation, and interaction
- Coursework materials and laboratory exercises delivered in a paced manner to support face-to-face and distance-learning curriculum

The desktop VR is delivered through a simple website enhanced with a browser plug-in (illustrated in results section). The website's content is arranged in a simple lesson format. The lessons are arranged by increasing complexity and difficulty with the more essential and fundamental topics being discussed first. While there is no system in place to prevent the user from accessing the more difficult lessons first, they will require knowledge from the previous tasks in order to progress. Not including a system to allow only those who have completed previous tasks to enter the later levels was done to let those with previous programming experience to skip topics with which they are already familiar. Each page follows a similar structure in their layouts. First, the topic is explained to the viewer using a combination of text and images. This content was designed to be very simple and easy to understand. The concepts involved in 3D Modeling and animation serve as basic notions for various intermediate and advanced CG courses. A framework that not only introduces, but also provides a good working knowledge of modeling and animation concepts is not easy to find.

The following are some of the drawbacks among existing approaches:

• Textbooks using difficult language/structure that is not easily understandable by undergraduate students
• Not delving deeply into the basics, which makes understanding the advanced topics difficult
• Not covering the mathematical /geometric /trigonometric foundations of modeling

• Improper and inadequate use of interaction

Typically, VR involves Immersion and Interaction, in addition to which Burdea & Coiffet (2003) include Imagination to make the 3 Is. In addition to the immersion and interaction offered by the photo-realistic VR simulations, the ability to interactively manipulate the components and combine/transform them allows for imagination, which can be a valuable asset in design prototyping and ideation. The content and structure of the framework was developed to cover the following important introductory concepts, namely:

- Coordinates, dimensions, and coordinate systems (Figure.1)
- Points, lines, and polygons, Shapes & Forms (Figure.3)
- Geometric Transformations
- Absolute and relative values
- Global and Local Coordinate Systems
- Mesh Modeling

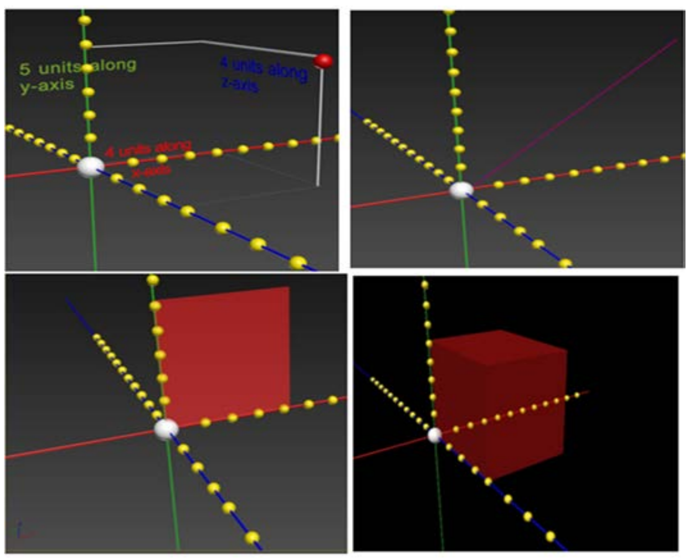


Figure. 2: Building Models in Coordinate Systems

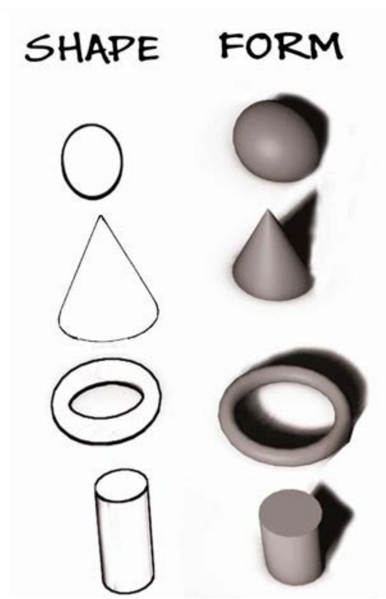


Figure.3: Shapes & Forms

Typically, graphics programming languages and modeling platforms approach the notion of transformation in one of the following two ways. One way is to consider that an object itself is transformed, either by translation, rotation, or scaling. In such a case, if a street lamp object is translated, this can be thought of as the transformation is being directly performed on the shape itself. It is also possible to approach transformation from another standpoint wherein the coordinates system itself is transformed and the object or objects in it are also subject to the transformation (to which the coordinate system was subjected to). Typically, the notation (X, Y, Z) is used to refer to the original coordinate system and (X', Y', Z') denotes the transformed coordinate system. The movement, shift, or rotation of the transformed element will be governed by its new coordinate system.

For clarity and ease-of explanation, the results section has been divided into 2 parts

1. Workflow and Hardware Results
2. Advanced CG concepts

Results (Part 1) Framework Workflow and Hardware

Using a virtual workflow, basic 3D operations were explained through interacting with the objects in the 3D environment (Figure.3). This virtual workflow facilitates interacting with 3D objects (books, in this case) and learning 3D transformations through the following operations:

- Translation (selecting and moving books and positioning them in shelves, *as in a library*)
- Rotation (re-arranging shelves within the library 3D space by re-orienting them)
- Scaling (increasing or decreasing the size of objects in the 3D scene)

Consider the example of building a house or manufacturing things. Numerous aspect of site layout involve spatial arrangement of various site elements similar to the arrangement of the various elements of house design such as location of doors, windows, etc (Figure.4). When considering the assembly of components in aircraft design, automobile manufacturing, the measurements and spatial organization is extremely important. Things in many systems including man-made systems, natural systems and biological organisms are located in a specific way: precise location is extremely important in modeling. However, in computer systems, it is much convenient to use positive and negative numbers. Instead of mentioning, up and down, positive and negative y axes are used; similarly, for locating to the right or left, we use positive and negative x-axis, instead of, and similarly, for front or behind, we use z-axis. To explain the above concepts, a simple and practical example for chosen and students interact with this in the VR scene. Students in a university are typically well-acquainted with the library setup and are familiar with the library environment. Hence, a 3D VR-based common example of stacking books and arranging the layout is used to explain the fundamental concepts of transformation.

Figure.4: Virtual Workflow to facilitate Interactive Learning of 3D Transformations

While different computer graphics (CG) software employs different steps to create models, in essence, the fundamental idea is to approximate the shape of the object that is being represented. Modeling an object essentially involves capturing or recreating its shape. When we see a finished model we are actually seeing the surface, which is a polygon or a collection of polygons. Building 3D models involves creating and assembling (or organizing) the polygons (or faces) to resemble the object being represented. The vertex (or a point) is created within a reference system also known as the coordinate system. Hence, in order to create polygons within the modeling environment, you need to understand coordinates and coordinate systems. Table 1. below summarizes the VR modules that were generated and those that are still being developed.

Table.1 **Summary of VR modules generated for CG concepts**

Computer Graphics Concept	**VR functionalities REQUIRED to facilitate learning**		
Coordinates, dimensions, and coordinate systems	Immersion	Interaction	Navigation
Points, lines, and polygons	¤√	¤√	¤√
Geometric Transformations	¤√	¤*	¤*
Absolute and relative values	¤√	¤√	¤√
Global and Local Coordinate Systems	¤√	¤√	¤*
Mesh Modeling	¤*	¤*	¤√

¤ - Required
√ -Implemented
* - Not Implemented, Work in Progress

For the hardware implementation part, the options that were considered for were the Samsung Odyssey, Google Card Board Headset (GCBH), and Dell Visor (Figure.1). In order to determine the best system for the study, a comparative analysis was created using the Oculus/HTC as the basis to compare the other systems.

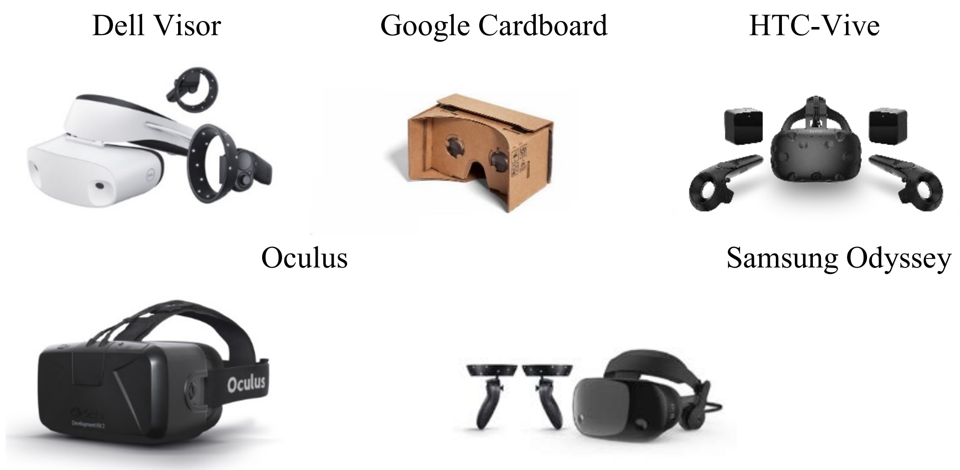


Figure 4. Cost-effective VR Systems Compatible with Framework

Finally, Dell Visor was selected to implement the VR modules to explain the concepts, for the following reasons. Dell Visor can be plugged into any PC and desktop that is able to run windows 10. However, an adapter and dongle are needed to properly have the system run with a desktop. The adaptor has to a Mini display port to HDMI video adaptor converter; we choose this also, because it needs to be able to support 4K. The dongle is a Bluetooth 4.0 LE + EDR to plug into a USB port; this is needed if the computer does not have built in Bluetooth.

This system can be used to facilitate CG instruction through interactive learning exercises and active learning in Engineering and Technology curriculum. In addition, students in various ET disciplines can use this framework to apply CG concepts in their discipline-specific applications. From Figure.3 we see that eventually, the fundamental elements that were assembled together to form a scence put together thereby enabling students to understand the concept of transformation.

Figure.5 shows the multiple modes Multiple modes of interaction via

- Standard Gaming Mouse/Keyboard
- Wacom © Tablet/Stylus
- Dell © Touchpad
- Razer Hydra ©

Results (Part 2) Advanced CG Concepts: Photorealistic 3D Objects and Scenes for Interactive Instruction

A complete library of 3D objects has been built to help students help students understand the basic concepts demonstrated earlier has been developed so that students can use such real-world examples to understand and practice the above theoretical aspects (Figure.11)

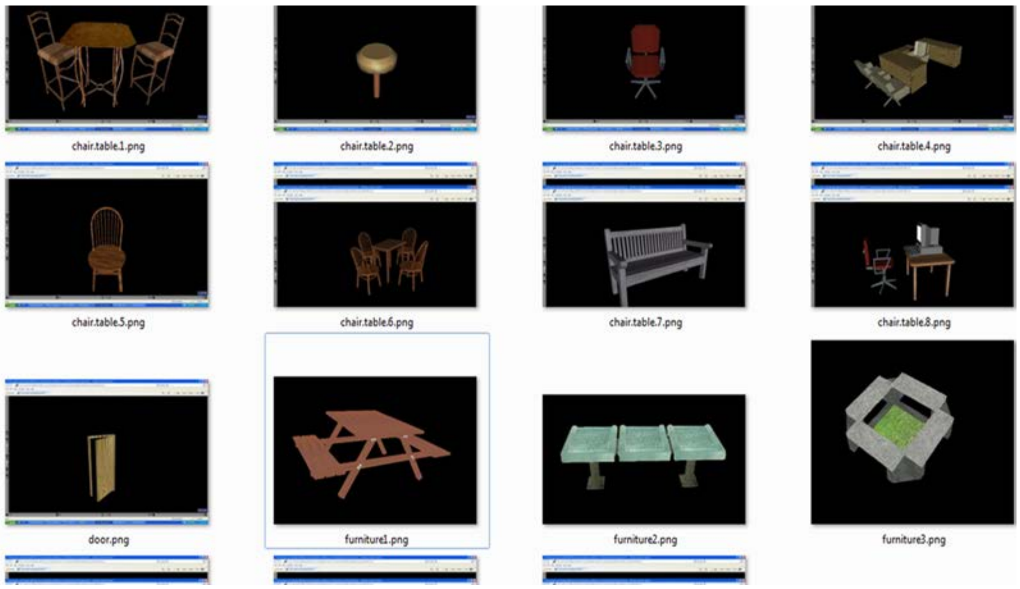


Figure.5: Library of 3D Virtual Objects for Interaction

Summarily, the advantages of the framework and how it can help realize the course learning outcomes and develop students' skills is depicted in the table below.

Table.2 VR Framework and Role in Enhancing CG Skill Sets

Ability / Skill	Description	VR Interaction's role in enhancing the Skill/ability
Spatial ability	Deals with the capability to interact with and control/manipulate 3D shapes.	Framework facilitates interacting with 3D objects and helps understanding spatial dimensions and performing 2D and 3D transformations.
Mathematical Skills / Geometric Skills Projective Geometry - Euclidean Geometry	The skills essential to performing quantitative calculations and computations.	Framework aids understanding the quantitative parameters in shapes and forms; interacting to adjust distances between objects, models, and various elements of final 3D scene. Helps understand - Plane Geometry - Solid Geometry
Artistic Skills	Creative aspects involved in modeling and animating	Framework helps alternative scenario visualization to • Stimulate creativity and imagination • Evaluate alternative scenes
Digital Skills	Represents the ability to translate ideas from sketch to 3D models	Framework can help modelers, and animators to practice in a digital setting to enhance their digital skills.

Table 3 below provides an overview some of the fundamental CG concepts that have been covered within the VR framework that can be accessed via multiple modes

Table.3 Illustration of Basic CG concepts within the VR Framework

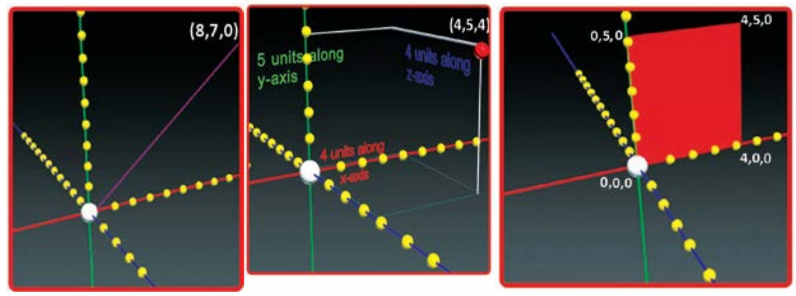
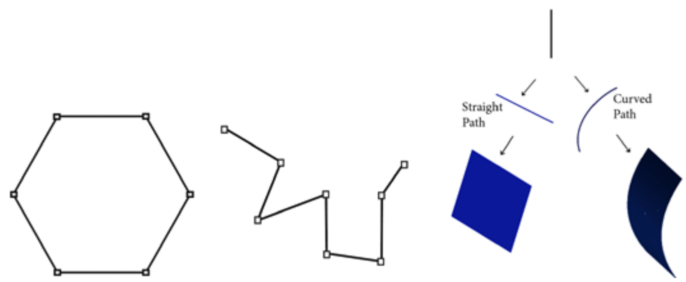
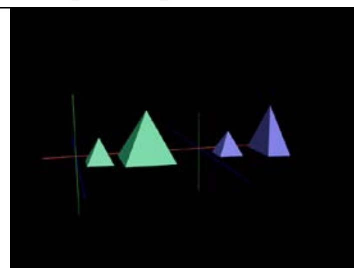
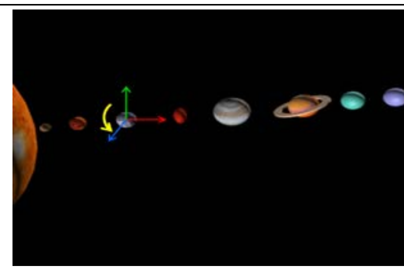
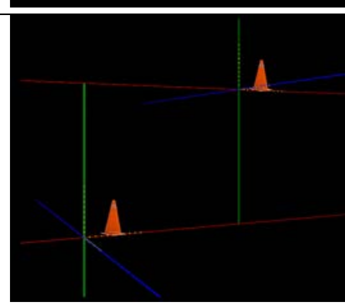
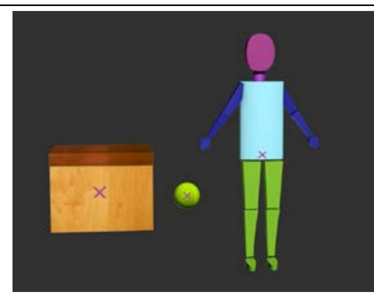
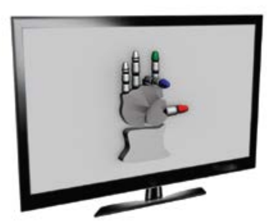
Coordinates, dimensions, and coordinate systems	
Points, lines, and polygons	
Geometric Transformations	 
Absolute and relative values	 
Left handed and Right Handed Systems	 

Table 4 below provides an overview some of the intermediate to advanced CG concepts that have been covered within the VR framework that can be accessed via multiple modes

Table.4 Illustration of Intermediate CG concepts within the VR Framework

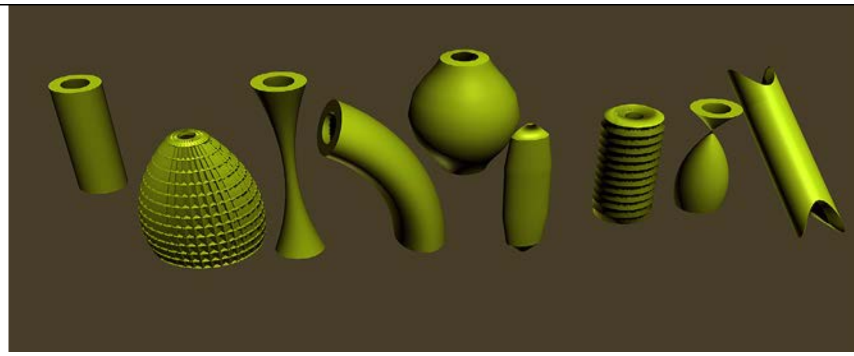
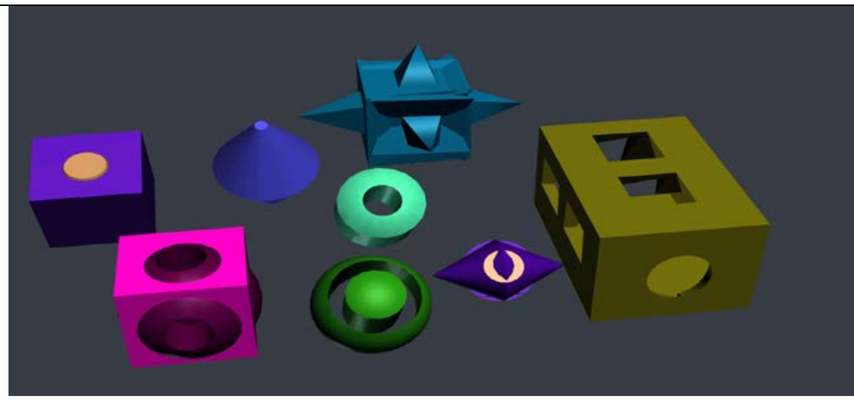
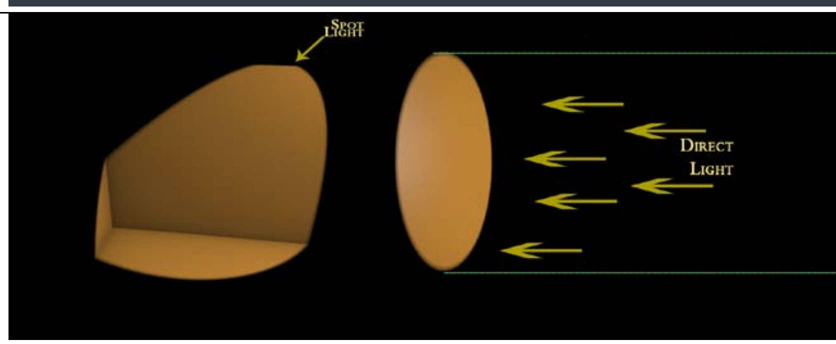
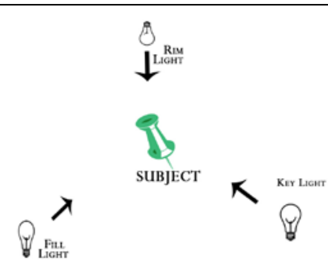
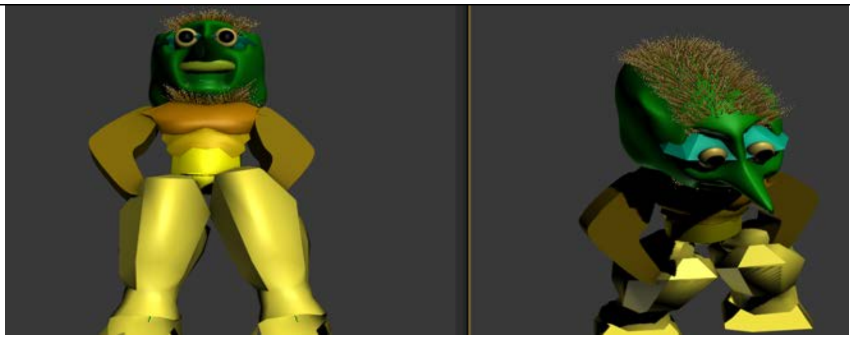
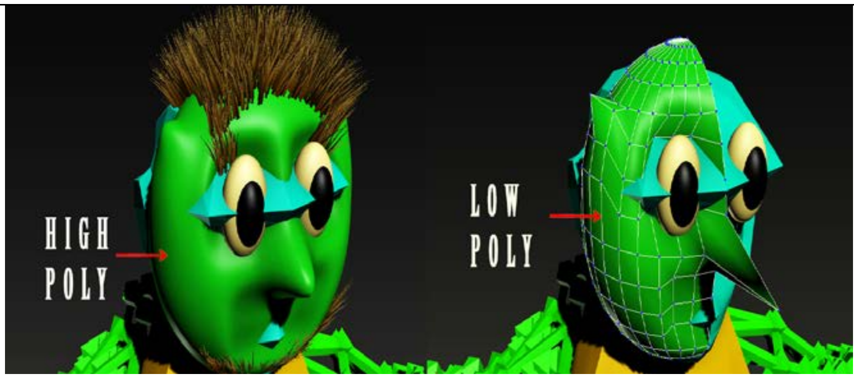
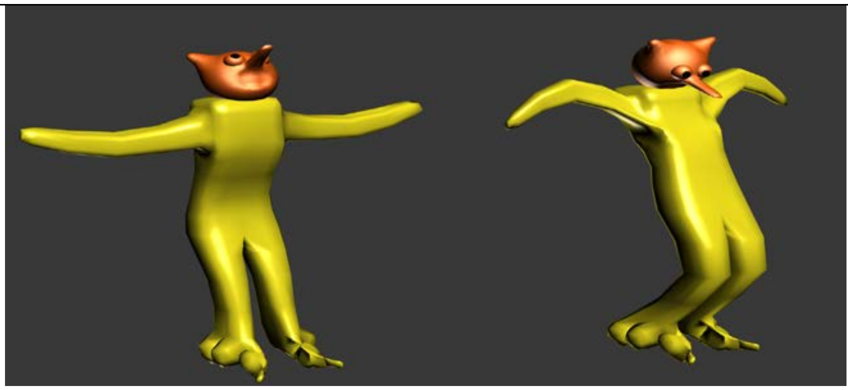
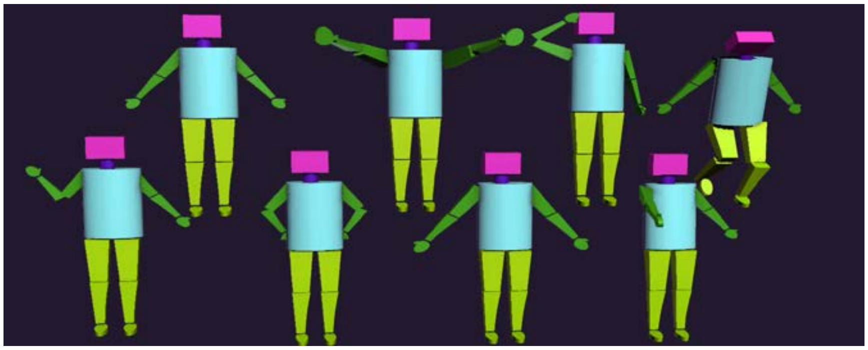
3D Modeling	
Constructive Solid Geometry Proboolean Union Intersection Subtraction	
Lighting	
3 Point Lighting	 

Table 5 below provides an overview some of the advanced CG concepts that have been covered within the VR framework that can be accessed via multiple modes

Table. 5 Illustration of advanced CG concepts within the VR Framework

Low-Angle Vs High Angle Shot	
Polygon Count	
Composition Clues for Emotion	
Posing	

Finally, putting together all these individual 3D objects and positioning and orienting them helps build different 3D scenes as shown below.

The following are some very important results demonstrated from this framework:

- A coordinate or coordinates is/are the numerical representation(s) of the location or position of an object.
- The origin is typically at the center of the reference coordinate system. However, the origin need not necessarily be at the center of the modeling space.
- Different conventions are used by programming language and modeling platforms that are available and used for modeling 3D objects and scenes.
- Transforming objects within a 3D CG scene refers to moving objects or groups of objects and altering their shapes, proportions, and sizes.
- Three broad categories of transformations include translation, rotation, & scaling
- Graphics modeling environments control transformations using what are known as transformation matrices.
- The basic building blocks used in modeling are points, lines, and polygons

Limitations

As this is a work in progress, the framework need to be further developed and then these modules will be tested in CGT courses with IRB approval. Also, the basic concepts in computer graphics span over a wide range of topics that vary according to the software languages and modeling platforms. Based on the literature review this study has narrowed down on the very basic concepts that are common to different CG courses across the nation. Detailed feedback will be obtained from the participants and comprehensive quantitative/qualitative evaluations will be carried out. These will be presented in conferences and published as well. Furthermore, focus groups of participants will be included during the workshops to actively engage other instructors as well and solicit their critiques on methods implemented thus far and for future enhancement.

Conclusion:

This framework allows the users to interact with the objects on the VR display not only via the standard mouse and keyboard, but also using multiple forms of HCI such as Touchscreen, Touchpad, and 3D Mouse. Hence, the modules were developed from scratch for access via regular desktop PCs. Such a framework helps effective pedagogical strategies such as active learning (AL) and project-based learning (PBL), which are especially relevant to a highly lab-oriented course such as this course titled 'Introduction to Animation'. This project employs an innovative pedagogical approach using multi-modal VR for CG instruction specifically targeted at 4-year degree programs. In addition to CG (computer graphics), 3d modeling and animation courses are also taught in various other engineering and technology disciplines. In this paper, the framework discussed is primarily from the point of view of a technology curriculum with more emphasis on the application. However, some basic theoretical aspects of modeling and animation are inevitable in order to create 3d models and animate them. Summarily, the salient features and the advantages of the framework are as follows:

- Simple and straightforward approach aiding coherent flow
- Ample VR examples to explain CG concepts
- Active learning via interaction to facilitate underlying mathematical concepts
- An easy to understand, VR- based approach for explaining advanced concepts

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