Creating a Novel World Builder Application in an Immersive Virtual Reality Environment

James Hall* Matthew Stoltenberg† Arun Augustine‡ Kaushik Sivakumar§
Nithya Ningegowda¶
University of Texas at Dallas, CS6301.006, Group 6

Abstract

People have a dream of building their own world.While it may not be possible in real life, it is possible through virtual reality. We describe a world builder system (WBS) which is based on Bruce Branits seminal science fiction film called the "World Builder" where people can build their own world. The idea behind the world builder concept is simple: Create a world in which the user can craft other worlds. The World Builder was built using the Syzygy API and arMasterSlaveFramework. We provide three interaction techniques (Selection,Manipulation and Navigation). The interaction is done with the Head-Mounted Display and two 6 Degree of Freedom (6DOF) Wiimotes using concepts such as Virtual Hand,Ray Casting, PORT, real walking, and virtual walking. Manipulation is done through both a menu interace where users can create, delete, or apply textures to objects, and gestures using the two Wiimotes. This project allows a user to design a virtual world around themselves, allowing the user to easily bring to life their imagination.

1 Introduction

World builder is a concept of a meta-world that can be used to imagine and create new worlds. It provides the necessary tools in an immersive environment to aid this process of creation in the most natural way possible. We live in an era of the meta-tool: the computer which like the greek mythology of Proteus can assume the form of any tool that can be imagined. But the 2D desktop environment still present some degree of cognitive distancing from what we imagine in our minds and what is manifested. The world builder concept aims to reduce this cognitive gap by placing the twenty- first century descendants of Homo habilis (the human tool user) in an immersive environment where they can craft objects and observe them being formed at the tip of their fingers.

The concept of the world builder is not new. In 2007, filmmaker Bruce Branit released short filmed titled "World Builder" [5] which portrays a man using a futuristic 3D interface to create a small town from scratch starting with simple geometric shapsn progressing through various levels of detail. The user goes about creating these with an ease of creating a painting.

The goal of this project is to implement an immersive 3-Dimensional interface that will facilitate the building of a virtual environment from scratch, in the most natural and easy way for users, at the same time not limiting the user with respect to their creative abilities and imagination. A minimum viable implementation of the world builder would include tools that enable the user to construct virtual objects; place prefabricated models within the world; manipulate objects in terms of translation, rotation, scaling, or texturing; and a way of navigating this virtual world.

The envisioned applications of the world builder tools are many. Firstly, it can be a most amenable educational tool. There is a growing body of studies that suggests that human beings learn by what is called embodied simulation. Any new concept is processed in our minds through simulated use of our five senses in the cognitive process of understanding it. A good example of this would be the use of lego construction set to learn about 3D geometry and spatial co-ordination. Another contemporary example is the use of minecraft in teaching history, in which the students re-create and explore a historical setting in the sandbox game. The world builder can be the ultimate tool to create your own lego set or to portray a narrative which can then be used in teaching projects. Since both the creator and the user can be immersed in a virtual environment which can simulate both real world physics and any imagined unreal (read magical) dynamics of objects, such a platform can be very versatile.

Secondly, the world builder is relevant in the computer aided design field. Immersive CAD applications have been already developed but not for building an entire world. The world builder application would be able to create an entire city instead of designing one single building in an immersive environment. The world builder would not only be able to create single entities but would also enable the study of the dynamics of a system that contains a multitude of objects. Finally, the movie and the entertainment industry has historically been the largest consumer of virtual reality applications. The world builder concept has immense utility for laying out a scene either for storyboarding or to be rendered in an animated movie.

This project aims to identify functionalities supported by existing CAD systems, conceptualize functionalities specifically for world building, design a 3D user interface that will support these old and new functionalities which will provide an interaction that feels intuitive and natural to the user and finally, and create a minimum viable product that contains a subset of these functionalities as a proof of concept. Section 2 outlines previous work done by other groups. Section 3 outlines the design of the end result. Section 4 details the plan of action for creating the prototype application.

2 Related Work

While computer power has increased exponentially over the past several years, we still rely on the same interface that was created over 20 years ago, namely a 2D screen with interaction through a keyboard and mouse. While this is sufficient for every day tasks, it is quickly becoming more and more cumbersome on designers of 3D objects (architects, mechanical engineers, 3D artists, etc)[8].

It has been shown that creating 3D objects within an Immersive Virtual Environment (IVE) has significant benefits over developing on a 2D surface (a monitor)[13], especially in a classroom setting[14]. Our application will allow a teacher to create an interactive 3D model to be used for instruction of students.

We plan on breaking the design in to several pieces such as creation, editing, and grouping. This allows the user to focus on the task at hand, creating a more efficient workflow[6].

*jmh045000@utdallas.edu
†mjs010200@utdallas.edu
‡axa117120@utdallas.edu
§kxs104820@utdallas.edu
¶nithyang11@gmail.com

Other research has given evidence that careful attention needs to be placed on the method of interaction[4]. We will be using several interaction techniques.[1] Bimanual interaction has been shown to allow the user more fine-grained and contextual control[22]. Some research has shown that using an augmented reality system to construct a virtual world along side a real one provides intuitive benefit[12]. Since we are using 6DOF devices based on where the users' hands are, we can take advantage of proprioception. This allows the user to have a more phyical "sense" of where the object is being moved [16]. We allow the user to point and select in a 3D space, which gives the user more fine-grained control of indvidual points on the object [11]. This could be extended to allow a user to manipulate individual points (vertices) on an object, giving very precise control of the detail of the object. Dexterity in IVEs is also a problem, one group used a pressure sensitive notepad tracked in 3D to simulate a digitizer which allowed manipulation of objects in the environment[19]. We will be overcoming this problem by using two 6DOF devices for interaction, this way, the user will have very fine control over each object.

Selection techniques often use ray casting. Some work focused on pointing from the user's hand[16]. Others used the user's eye as the start of the ray[18]. More recent research has indicated that a combination of the two leads to the best results for user accuracy[2]. We will be focusing on simple ray-casting, although the system can be extended to allow for any number of selection methods to be chosen by the user.

There have been extensive studies on locomotion within IVEs, such as World in Miniature[17]. We will be using a modified World in Miniature scheme. The user will be able to shrink the world around them, thereby allowing them to navigate quickly and efficiently, without taking up valuable space in the display.

One feature that is very promising is the automatic creation of object based on shape grammars[10]. This allows a user to define a "rule" for creating an object, and the system can create multiple variances of that object for them.

There is evidence portraying the lack of useful computer based tools for architecture, especially within architecture education[9]. Our system will allow the design and study of full-scale buildings in minute detail. Once real-world simulation effects are in place, the user could add a life-size skyscraper and view the effects of gravity and wind at the top floors.

The ability of an IVE to design and view 3D models dynamically extends well beyond architecture and simple CAD. Volkswagen has been designing a virtual reality system, RAMSIS, that allows its engineers to study the styling and design of their vehicles before production[20]. We believe we can take this one step further: by allowing a user to bring a model in to the world, the user can design an entire world and place objects, such as cars, within it.

Another exciting possibility for the uses of a generic 3D design system is that of Micro-Electro-Mechanical Systems (MEMS)[23]. By extending our system to allow for real-world simulation effects, the user could prototype the device and study its behavior in an intuitive manner.

To imporve the real-worls simulation effects, we need to add to haptic feedback[15] and auditory cues[3] to the system. Few systems have already been developed to should the effect of using haptic feedback[21] and 3D sound[7].

3 Design

3.1 Physical Environment

The real-world environment that the user will be tracked in is 10'x30'. The user is provided with a Head-Mounted Display and two 6 Degree of Freedom (6DOF) devices with 11 buttons each (Wiimotes) (see Figure 1). The tracking of the head and each Wiimote is done with a Vicon system placed around the tracking area.

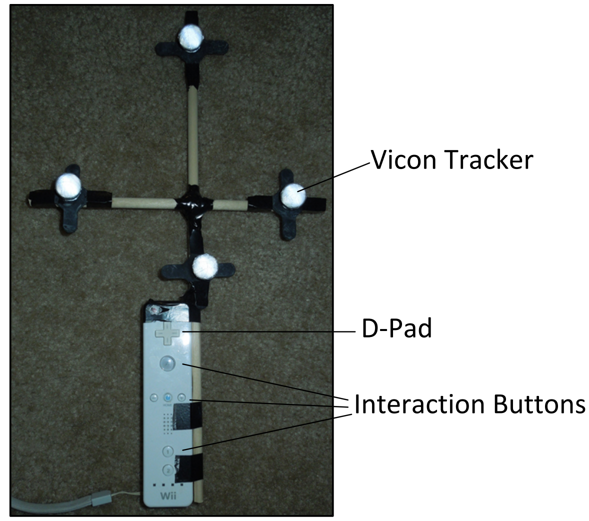


Figure 1: Wiimote with Vicon trackers

3.2 Virtual Environment

The virtual environment is an empty and infinite 3D canvas for the user to create a virtual world. This allows the user to create any object, building, landscape, or geometrical feature that is possible, with any size imaginable. Since the user is creating a world, there are no sounds, animations, or simulation effects in place to begin with. However, the user may create any item within the world, which can be utilized to create moving objects, 3D sounds, and simulation effects. For instance, the user can create a car that moves along a street, with associated engine and tire noise as it moves. The user could also create the ground and say that objects must "rest" upon the ground (simulating gravity).

3.3 Interaction

3.3.1 Selection

Object selection is a crucial task for most of the features within this project. We will be augmenting object selection with tactile feedback provided through the Wiimote's rumble feature. When a user selects a new object, the Wiimote will rumble for a predetermined amount of time. Several selection selection methods are provided, which can be selected based on the users preference.

- Simple Virtual Hand
- Simple Ray-Casting
- PORT

Simple Virtual Hand A virtual hand will be co-located with the user's real hand. The user will not be able grasp any objects out of their reach, and must navigate to manipulate them. This method of selection is the easiest to understand and use but affords the least flexibility.

Simple Ray-Casting This is similar to Simple Virtual Hand, however the user is able to reach out to infinity or until an object is encountered. This affords the user to be able to manipulate objects that are very far out of reach but requires the user to learn to take advantage of this. We believe this will require little cognitive overhead and should not cause problems for most users. As such, this will be the default selection method.

PORT The user can create a 3D selection box where all objects within the box become selected. This selection method provides the most flexibility, especially within our application, however the cognitive overhead on the user is higher. Once a user is proficient with the system, we believe this will be a frequently used selection method.

3.3.2 Manipulation

There are several manipulation techniques provided.

- Single-Object Manipulation
  - Creation
  - Deletion
  - Translation
  - Rotation
  - Scaling
  - Coloring
  - Texturing
- Multi-Object Manipulation
  - Boolean Operations
  - Grouping
  - Deletion
- World Manipulation
  - Scale-the-World
  - Light creation/manipulation
  - Sound creation/manipulation

Single-Object Manipulation This subcategory of manipulation is dedicated to a user manipulating one object at a time. Creation and deletion will be done through a menu (described 3.3.4), however deletion will require an object to be selected first. Translation, rotation, and scaling will all be performed with button interaction on the Wiimote, after an object is selected. Scaling is unique, as it requires bimanual input. The user must select and object, press buttons on both Wiimotes, and move both hands for the object to be scaled. The actual motion will be determined by the hand movement while the interaction button is being held down. Coloring and texturing will also be performed through a menu (see 3.3.4) and will also require an object to be selected first.

Multi-Object Manipulation There are three boolean operations using multiple objects provided. Boolean operations can be performed when there are overlapping portions of multiple selected objects.

1. Union

   When the user selects the union operation and multiple objects are selected, it creates a single, fused, object made up of all the objects that were selected.

2. Intersection

   When intersection is selected, the non-overlapping portions of the selected objects will be removed, leaving a single object made up of only the intersecting portion.

3. Subtraction

   This operation is limited to two selected objects. When subtraction is selected, the user chooses a primary object, and the overlapping portion of the primary object is removed. This operation leaves two objects, however the primary object is now missing the overlapped portion.

Grouping objects allows the user create a single object from a group of selected objects. Unlike the boolean operations, no logic is performed on the group other than making them behave as a single object. The grouped objects, for all intents and purposes, behave as a single object, all the single object manipulations above work on a grouped objects. One benefit grouped objects provide over the boolean operations, is that it can be undone. Multiple objects can be grouped, manipulated, ungrouped, and manipulated independently. Grouping objects will be performed through the menu described in 3.3.4.

Deletion is the same as single-object deletion, however it allows the user to delete multiple, unconnected objects (as long as all are selected).

World Manipulation When the user grabs the air with both hands, and performs the scaling operation, the entire world will be scaled up or down, according to the user's movement. This allows the user to navigate more easily, as well as create very large structures within the virtual environment without too much effort (simply scale the world down, create a normal object, and scale the world back to normal size).

Light creation and manipulation allows the user to create lights, move them, and change aspects of the lights to suit the application (color, attenuation, direction, etc...).[1] The same ability exists for sounds. The user can create a sound, attach it to an object, and the sound is then created from a specific point in space.

3.3.3 Navigation

Navigation is another crucial feature. Since the world is infinite, there must be a sensible way to navigate, otherwise the world will be limited to the size of the tracked area.

The main method of navigation will be real walking, since we have a 10'x30' space, the user will be able to walk in any direction within the space, and that motion will be translated to the virtual environment. Another navigation mechanism provided will be virtual walking. We will be using the D-Pad on the Wiimote to simulate a joystick. i.e. If the user presses "Up" on the D-Pad, they will move forward in the virtual environment.

Another navigation feature is to use the manipulation feature Scale-the-World. Since the user can scale the entire world down, they can make everything smaller, making their steps (both real and virtual) much larger. This method loses some interaction fidelity for the benefit of an infinite world.

3.3.4 System Control

As mentioned before, a menu will be present. The menu is created in 3D space where the user's right hand is when activating the menu. The menu is a collection of categories laid out in tabs, with buttons under each tab for the functions available in that category. The categories provided are:

- Objects

  Allows the creation of default objects (sphere, cube, cone, etc...)

- Materials

  Contains a collection of colors and textures to apply to objects

- Tools

  All of the advanced interaction methods listed above

[1]Technical note: We are using OpenGL, so the number of lights in the world is limited to 8.

- File Operations

  This category is unique, as it doesn't pertain to editing the world. This category contains operations to save the existing world to file, load a file as an existing world, export an object to use again later, and load an object that was previously exported.

See Figure 2 for a mock-up of the menu.

3.3.5 Grammar based Production of Objects

A grammar or rule based production of objects will allow to specify a set of rules to the application, either pre-set or user programmable that will automatically create objects in the pattern specified by the rule. This feature may be implemented in two ways. One in which the user directly specifies the production rules or recipe to create the object in the specified pattern and second, the system learns the underlying grammar or pattern from a set of exemplars created or loaded by the user. However this is an advanced feature and maybe beyond the scope of the current project.

4 Plan of Action

We will be implementing a prototype world builder over the course of one semester. This prototype will stay true to the design, however, due to time constraints, not all features will be included.

4.1 Physical Environment

The physical environment remains the same between the end-goal and this prototype phase. We will still be using a Head Mounted Display, along with two Wiimotes. All will be independently tracked using a Vicon system in a 10'x30' space. Also, the Wiimotes provide 11 buttons each, that will be used for interaction and navigation (see Figure 1).

4.2 Virtual Environment

The virtual environment will still be an infinite world, with a goal of letting the user design any object, building, landscape, or geometrical feature they can imagine. However, simulation effects such as gravity and animation will not be included. The user can still create objects and place them together to make more complex and larger objects, but they will not be able to give them motion.

Sound (as well as light) creation/manipulation are optional features that we hope to add in to the prototype. See World Manipulation below.

4.3 Interaction

During this prototype phase, the most important aspect is the interaction abilities the user has.

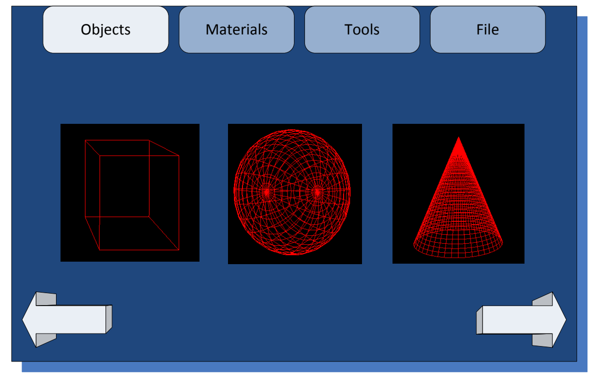
4.3.1 Selection

We will be implementing both the Simple Virtual Hand and the Simple Ray-Casting. Both will be drawn using a 2'x2' rectangular prism. When in virtual hand mode, the prism will be 5' long, with the tip where the user's hand is. In ray-casting mode, the prism will extend, up to 1000', until it reaches an object. Since PORT is not being provided in the prototype, multi object selection will require the user to select objects in turn.

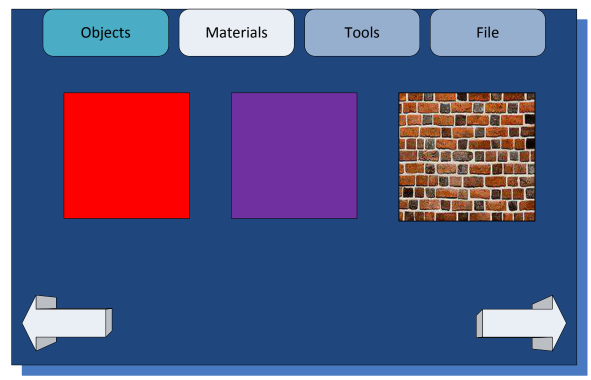
4.3.2 Manipulation

Single-Object Manipulation All features discussed in the design section for single object manipulation will be included. The user will be able to create, delete, translate, rotate, scale, color, and texture all objects within the world.

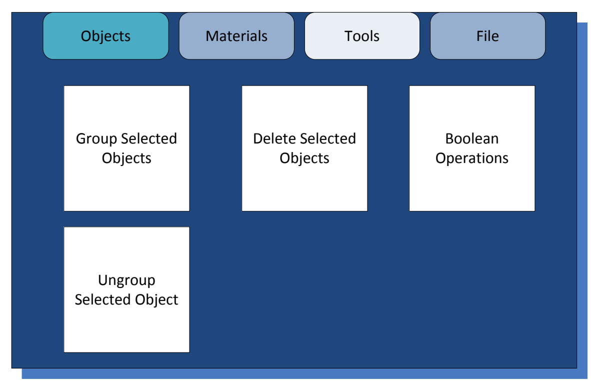
Multi-Object Manipulation Boolean operations will not be provided in the prototype. However, the user will be able to group multiple objects to form a single object, and delete multiple selected objects.



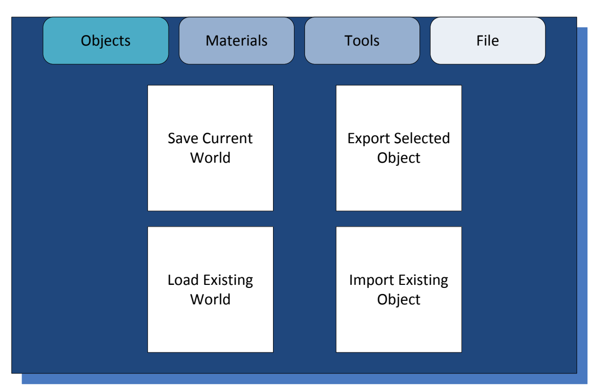
(a) Object Menu



(b) Material Menu



(c) Tools Menu



(d) File Menu

Figure 2: Mock up menu interface

World Manipulation Scale-the-World will be provided. This feature is essential given that the size of the world is so big, and the user will need to navigate large spaces.

Sound and light creation will be focused on last. If there is time permitting after the essential manipulation features have been implemented, light and sound creation and manipulation will be included.

4.3.3 Navigation

Both real walking and virtual walking will be provided. Real walking is accomplished by the framework with little effort. Virtual walking will use the D-Pad and move the origin point of the environment, thereby moving the user through it.

Since Scale-the-World is provided, as well as both walking schemes, the user will be able to magnify their steps using the method described in 3.3.3.

4.3.4 System Control

Many of the features described in 3.3 require a menu, so a menu will be provided. However, this will be simpler than the menu described in 3.3. An object category and material category will be provided, as well as a tools category. The tools category will only contain the features described in this section, namely, deletion and grouping.

If time permits, the file category will be provided that will allow the user to save/load the world they have spent time to create.

4.4 Implementation

We will be implementing the World Builder application using the Syzygy virtual reality API created at the University of Illinois for the development. This API allows us to do rapid prototype development, since some of the most complex features of an immersive virtual environment have been completed, including head based rendering, interaction with objects, and input device drivers.

The Syzygy API contains two frameworks that are used for development, `arMasterSlaveFramework` and `arDistSceneGraphFramework`. We will be using the `arMasterSlaveFramework`, but we are using a helper class created by the FIVE lab at UTD to include a Scene Graph in an `arMasterSlaveFramework`.

See Figure 3 for a Gantt chart containing tasks and time estimates. See Table 1 For an assignment of tasks to members of the team.

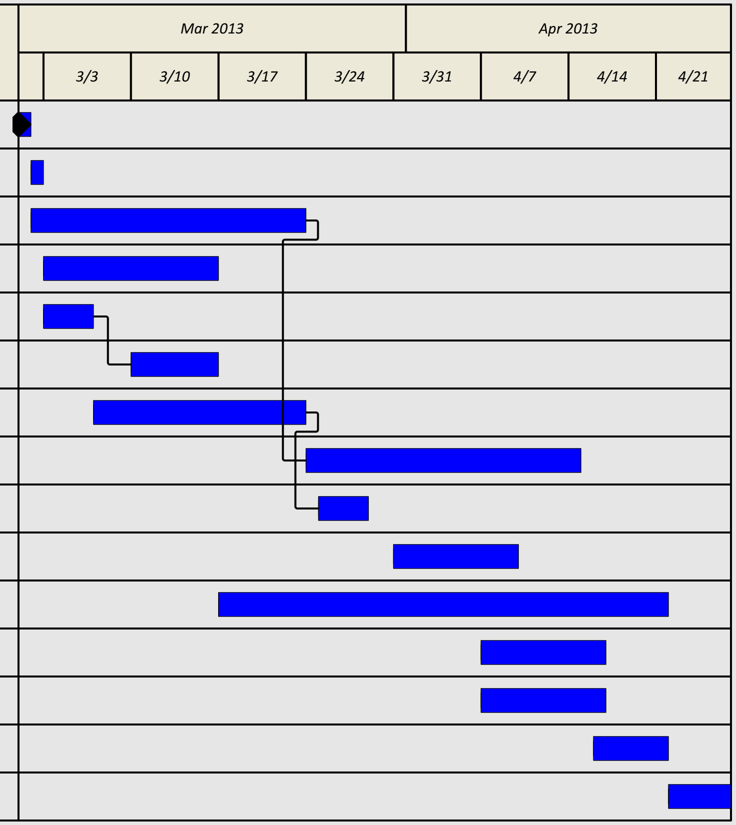
The list of required assets:

1. Solid objects drawn in OpenGL
2. JPEG texture files
3. Advanced 3D objects exported to OBJ format
4. Simple Ray-Casting
5. Object selection
6. Moving/Scaling an object
7. Menu creation
8. Menu interaction
9. Light creation/manipulation*
10. Miscellaneous sounds*

1	James Hall
2	James Hall
3	James Hall
4	Kaushik Sivakumar
5	Matthew Stoltenberg
6	Nithya Ningegowda
7	Arun Augustine
8	James Hall
9	Matthew Stoltenberg
10	Arun Augustine
11	Nithya Ningegowda and Kaushik Sivakumar
12	Any
13	Any
14	Any
15	All

Table 1: Tasks responsibilities

ID	Task Name	Start	Finish	Duration
1	Create a blank SceneGraph using the arMasterSlaveFramework	3/1/2013	3/1/2013	1d
2	Create templates for all basic objects to be created (Sphere, Cube, Cone, etc…)	3/2/2013	3/2/2013	1d
3	Create a menu usable within IVE	3/2/2013	3/23/2013	22d
4	Design advanced objects in Maya/Blender/ 3DSMax to use	3/3/2013	3/16/2013	14d
5	Integrate two arEffectors in to IVE	3/3/2013	3/6/2013	4d
6	Develop all single-object manipulation techniques	3/10/2013	3/16/2013	7d
7	Develop arDragBehaviors that use two effectors	3/7/2013	3/23/2013	17d
8	Bring up and use menu within IVE using Wiimote during runtime	3/24/2013	4/14/2013	22d
9	Develop the Scale-the-World interaction technique	3/25/2013	3/28/2013	4d
10	Develop all multi-object manipulation techniques	3/31/2013	4/9/2013	10d
11	Testing	3/17/2013	4/21/2013	36d
12	3D Sound creation and attaching to objects*	4/7/2013	4/16/2013	10d
13	Light creation (positional light)*	4/7/2013	4/16/2013	10d
14	Light creation (spotlight)*	4/16/2013	4/21/2013	6d
15	Package for submission, including documentation	4/22/2013	4/26/2013	5d



Tasks marked with '*' are optional, if the rest of the tasks are on schedule and working correctly

Figure 3: Development breakdown

References

[1] In *Understanding Virtual Reality Technology: Advances and Applications*, chapter 4, pages 53–71. 2011.

[2] F. Argelaguet and C. Andujar. Efficient 3d pointing selection in cluttered virtual environments. *Computer Graphics and Applications, IEEE*, 29(6):34 –43, nov.-dec. 2009.

[3] E. M. B. Kapralos, M. R. Jenkin. In *Presence: Teleoperators and Virtual Environments*, volume 17, pages 527–549. MIT Press Cambridge, MA, USA, dec 2008.

[4] D. A. Bowman. Interaction techniques for immersive virtual environments: Design, evaluation, and application. *Journal of Visual Languages and Computing*, 10:37–53, 1998.

[5] B. Branit. World builder, 2007. The information for this video can be found at `http://www.imdb.com/title/tt1419113/`.

[6] J. Butterworth, A. Davidson, S. Hench, and M. T. Olano. 3dm: a three dimensional modeler using a head-mounted display. In *Proceedings of the 1992 symposium on Interactive 3D graphics*, I3D '92, pages 135–138, New York, NY, USA, 1992. ACM.

[7] P. S. Daniel Doble, Michael Haller. pages 148–148. ACM New York, NY, USA 2002, 2002.

[8] K. Dekker. A future interface for computer-aided styling. *Design Studies*, 13(1):42 – 53, 1992.

[9] A. Dobson. Architectural composition in the electronic design studio: conceptual design using cad visualisation and virtual reality modelling. In *Information Visualization, 1997. Proceedings., 1997 IEEE Conference on*, pages 179 –185, aug 1997.

[10] P. Goswell and J. Jo. Real-time 3d city generation using shape grammars with lod variations. *World Academy of Science, Engineering and Technology*, 61, 2012.

[11] J. Grosjean, J. Simonin, E. Galin, and S. Merillou. 3d arrow: A virtual pointer for immersive sculpting. In *Virtual Reality Conference (VR), 2011 IEEE*, pages 209 –210, march 2011.

[12] R. Jota and H. Benko. Constructing virtual 3d models with physical building blocks. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '11, pages 2173–2178, New York, NY, USA, 2011. ACM.

[13] H. Kaufmann and A. Dünser. Summary of usability evaluations of an educational augmented reality application. In R. Shumaker, editor, *Virtual Reality*, volume 4563 of *Lecture Notes in Computer Science*, pages 660–669. Springer Berlin Heidelberg, 2007.

[14] H. Kaufmann and D. Schmalstieg. Designing immersive virtual reality for geometry education. In *Virtual Reality Conference, 2006*, pages 51 – 58, march 2006.

[15] J. J. L. Miguel A. Otaduy, Takeo Igarashi. In *International Journal of Human-Computer Studies*, volume 67, pages 237–255. Academic Press, Inc. Duluth, MN, USA, march 2009.

[16] M. R. Mine, F. P. Brooks, Jr., and C. H. Sequin. Moving objects in space: exploiting proprioception in virtual-environment interaction. In *Proceedings of the 24th annual conference on Computer graphics and interactive techniques*, SIGGRAPH '97, pages 19–26, New York, NY, USA, 1997. ACM Press/Addison-Wesley Publishing Co.

[17] R. Pausch, T. Burnette, D. Brockway, and M. E. Weiblen. Navigation and locomotion in virtual worlds via flight into hand-held miniatures. In *Proceedings of the 22nd annual conference on Computer graphics and interactive techniques*, SIGGRAPH '95, pages 399–400, New York, NY, USA, 1995. ACM.

[18] J. S. Pierce, A. S. Forsberg, M. J. Conway, S. Hong, R. C. Zeleznik, and M. R. Mine. Image plane interaction techniques in 3d immersive environments. In *Proceedings of the 1997 symposium on Interactive 3D graphics*, I3D '97, pages 39–ff., New York, NY, USA, 1997. ACM.

[19] I. Poupyrev, N. Tomokazu, and S. Weghorst. Virtual notepad: handwriting in immersive vr. In *Virtual Reality Annual International Symposium, 1998. Proceedings., IEEE 1998*, pages 126 –132, 18-18 1998.

[20] F. Purschke, M. Schulze, and P. Zimmermann. Virtual reality-new methods for improving and accelerating the development process in vehicle styling and design. In *Computer Graphics International, 1998. Proceedings*, pages 789 –797, jun 1998.

[21] G. Ye, J. Corso, G. Hager, and A. Okamura. volume 4, pages 3425 – 3431, 2003.

[22] R. C. Zeleznik, A. S. Forsberg, and P. S. Strauss. Two pointer input for 3d interaction. In *Proceedings of the 1997 symposium on Interactive 3D graphics*, I3D '97, pages 115–120, New York, NY, USA, 1997. ACM.

[23] X. Zhao, L. Wang, Y. Tan, G. Sun, and G. Lu. A novel design methodology for mems device. In *Nanotechnology, 2007. IEEE-NANO 2007. 7th IEEE Conference on*, pages 39 –44, aug. 2007.