Creating a Modular Weapons System

Tiffany L. Griffith and Boris Fisher

3D Art, Game Art, Modular System, Modular Weapons, Unreal Engine 4, Marmoset Toolbag 2.0,

Game designers consistently use modular construction systems to have reduced polycounts in games, especially for the environment. Building for modularity also increases performance by limiting the number and size of textures for each individual asset as well. However, game designers can apply modular systems to more than just the environment of a game.

This artifact consists of three game resolution weapons, made from a total of 30 interchangeable pieces including the body archetypes, and a smaller set of universal attachments for all weapon types. The presentation render, completed in Marmoset Toolbag 2.0, along with four texture sets (including two solid metal materials and two camouflage materials) for each modular weapon type are the means of analyzing the results of creating interchangeable weapon sets using a modular modeling system. The results include three fully rendered weapon types and over 2,000 possible combinations from the modular pieces alone and a minimum of 8,000 combinations from the additional materials that result from their modularity.

I. Introduction

Creating unique weapons for a game can take a considerable amount of time, and maintaining a large number of individual weapons and textures takes up a lot of space in the game. Applying a modular system to the creation of believably "unique" weapons can decrease the polygon and texture counts in game, as well as produce a significant number of weapons.

Developing a series of modular weapons with several interchangeable parts, including stocks, barrels, sights/scopes, grips, and magazines (depending on each weapon type) is the goal of this project. Each interchangeable part attaches to the body of the weapon at specific socket points, allowing for the creation of numerous different weapons from the same parts. The set also has four textures to apply to each weapon configuration, further increasing the visual customization. These textures include the standard black metal, desert tan metal, woodland camouflage, and Navy camouflage. The additional textures allow for a greater sense of customization with minimal time added to the project overall, and especially simplifies the ability to add more visual customization through the potential use in DLC (downloadable content).

II. Research Review

The research gathered to validate this thesis came from peer-evaluated articles, small arms literature, game media, and patents. Boris Fisher aided in the research by providing reference images as well as advice as to what should be researched. These sources provided insight for the creation of modular assets in a game engine as well as real-world examples of modular weapons systems, upon which lies the basis of this thesis. A few games that show significant relevance to this thesis include *Loadout* and the *Borderlands* franchise [1] [2]. They both utilize modular weapons systems heavily, albeit in different ways.

A. Literature Review

The first sources consulted included two books, Small Arms Visual Encyclopedia and Weapons: An International Encyclopedia from 5000 BC to 2000 AD, *Updated Edition* [3] [4]. Both of these resources contain visual representations of several different types of weapons, and assist with narrowing down weapon types for this project. The tentative weapon types for this project include an assault rifle, shotgun, and pistol. An initial sweep of these two sources yielded over 120 different weapons, and then later reduced the list to 65 after eliminating those with too much visual dissimilarity to the original weapon choice.

Since the modular weapons system in question for this thesis exists solely in 3-dimensional digital space, different problems arise for their creation. In an article by Paul Mader titled “Creating Modular Game Art for Fast Level Design,” he discusses specific techniques for the creation of modular assets [5]. He emphasizes the ability to speed up the process by which game designers can create levels using modular assets. While this topic specifically does not apply to the current hypothesis, he brings up valid points in the modeling process that are viable for use. In particular, he references grid points and the careful placement of pivot points so objects align to one another correctly. These principles apply greatly to the creation of modular weapons, since every interchangeable piece has to align to the body in exactly the same place every time.

Another work that focuses on modularity is Michael Musante’s thesis titled “Implementing a Hyper-Modular Art Creation Pipeline for Digital Games” [6]. He not only details the process by which to create these types of assets, but the problem-solving methods he had to utilize during the project. In this thesis, he explored the use of hyper-modular assets and the pipeline used to create them. The project aimed to study the creation of a hyper-modular asset pipeline. He specifically studied the problem-solving methods of creating assets for use throughout a game in many different ways, as well as a comparison of the effectiveness of hyper-modular assets versus “unique” assets. He found that the majority of testers believe that the level created contained enough assets to render the scene “believable,” which the current project aims to achieve as well.

B. Weapon Examples and Patent Review

Today, weapons manufacturers utilize modular weapons systems in order to allow for greater customization of weapons based on their purpose. They now use parts ranging from modular firearm rail systems for exterior attachments to stocks to fully- modular automatic weapons.

The firearm rail system patented by Stoner, Wilson, Palacios, Henderson, and Mott proposed different portions of railing for different parts of the weapon, including how to attach them to the barrel without obstructing grips for hands and the use of a shield to prevent the hand from coming into contact with the barrel during firing [7]. Creating generic rail systems such as these assist with the modularity of universal attachments used across all three weapons, such as flashlights and blade attachments.

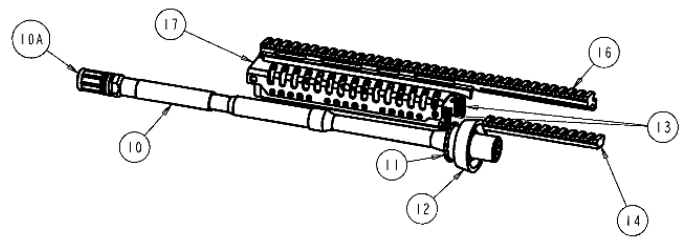

Figure 1: Preferred method for using rail system.

Fitzpatrick, Mayberry, E. Nakayama, and B. Nakayama developed a modular gunstock onto which users could mount additional accessories onto the weapon [8]. They diagramed all possible workable configurations, divided the weapon enhancement into the main components, and detailed them. They offer views of this stock as separate pieces as well as a complete product. They detail the weapon mounting structure, the sleeve module, and the rails that allow for accessory attachment.

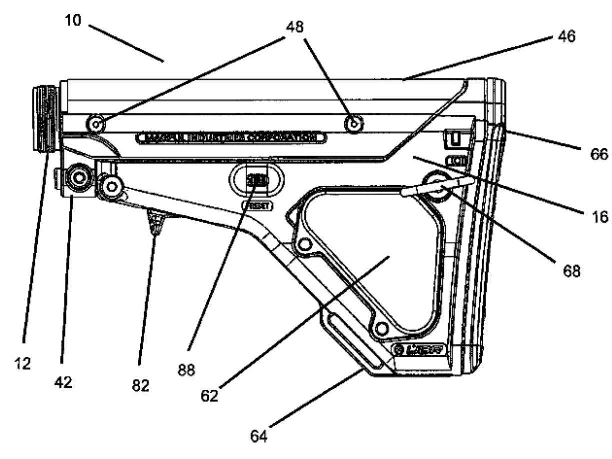

Figure 2: Modular gunstock as a complete product.

Johnson, Antwiler, McFarland, Meyer, Skahill, White, Witwer, and Wulff’s patent contains several images illustrating the connection points of every piece of this modular automatic weapon system, including the separate pieces and final products [9]. The authors presented a goal to increase the accuracy of such automatic weapons by increasing control of recoil forces. The authors claimed that the design of this modular weapon system would increase the accuracy of firing it. They provide detailed diagrams for each piece of the weapon from multiple vantage points. These diagrams assist with the building of assets in the current project because of the multiple vantage points of each piece of the weapons. This patent proves extremely helpful in the modeling of similar assault weapons for use within a 3D game engine. All of the above patents containing detailed information on the assembly assist greatly into the thought process used to model 3-dimensional weapons in a 3D modeling program.

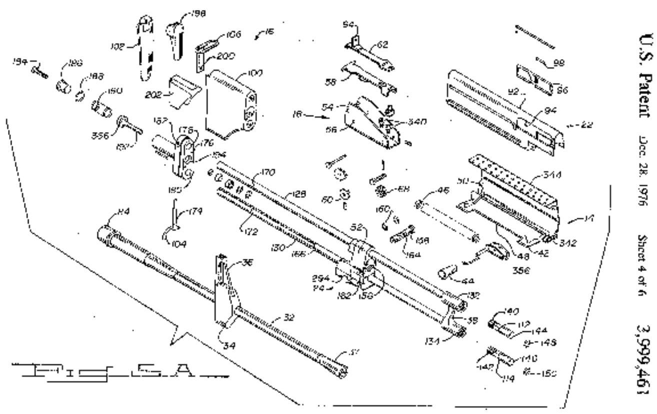

FIGURE 3: EXPLODED VIEW OF MODULAR LIGHTWEIGHT SQUAD AUTOMATIC WEAPON.

C. Field Review

Loadout, released in 2014 by Edge of Reality Ltd., utilizes a distinct weapon customization system similar to the current project [1]. Each weapon type uses the same body for the weapon, but then has several interchangeable pieces that include stock, barrel, magazine, trigger, and scope. The player can rotate the weapons in the customization menu in order to see all of the modifications as they make them. In addition, every modular piece drastically changes the silhouette of the weapon. After inspecting this system, one notices that the modular pieces of the weapons connect at all of the same junction points, which the current project also aims to emulate. The current project utilizes a similar system as this game does, including a functional user interface with all of the interchangeable parts of each weapon.

FIGURE 4: LOADOUT WEAPONS CRAFTING SYSTEM.

Borderlands 2, released by Gearbox Software and 2K Games in 2012, contains a vast number of weapons in the game, and each one has its own unique personality [2]. The game has developed a distinct visual style for each of its “brands” of weapons, as well as the individual weapon types, including assault rifles, pistols, shotguns, sniper rifles, rocket launchers, and sub-machine guns. This game serves as a basis for the ability to create visual distinction between not only weapon types, but also different guns within each type with the addition of a modular part, such as a barrel or scope. Figure 5 displays different barrels, bodies, grips, sights, and stocks for the different brands of assault rifles within the game. The current project aims to create a similar sort of “branding” to differentiate the types of weapons from one another while maintaining the same degree of customization and modularity.

FIGURE 5: BORDERLANDS 2 ASSAULT RIFLE CONFIGURATIONS.

D. Summary

Overall, researching weapon types by visual similarities assisted in the inspiration for the three final weapons for this project: the AK-47, Mossberg 500 tactical shotgun, and Colt M1911A1. Each of these weapons has the potential for complete modularity, albeit with different parts of each being modular. The patents showed ways to solve problems in making each piece modular by adding something else to it, increasing the asset list slightly but making the modeling process easier. Adopting a display system like the one shown in *Loadout* would work well for this project in terms of presentation, and the branding of weapons used in *Borderlands 2* allows for greater visual differences between the three weapon types [1] [2].

Creating and utilizing modular weapon systems continues to exist within game design, and optimizing these practices while developing assets to increase uniqueness of weapons benefits the development community. Learning to model in this fashion presents its own set of challenges, but identifying and overcoming these challenges early enough in the process limits the amount of rework and redesign during development. This project aims to create three modular weapon sets with interchangeable barrels, stocks, grips, sights, and accessories.

III. Methodology

This mastery-based thesis consists of three primary 3D model artifacts and specialized sets of secondary 3D models unique to each weapon type presented in a professional format. The three primary models each have secondary sets of modular attachments in an attempt to create multiple unique weapons from the same limited set of modular attachments. The textures included with each of these artifacts include an albedo map, metalness map, roughness map, normal map, and specular and detail maps as needed. Each artifact set has one primary texture set and three alternate texture sets.

A. Technical Details

Hardware used:

- Computer
  - Alienware
  - Intel 8-Core i7-4810MQ CPU, 2.8 GHz
  - Memory: 32 GB RAM
  - Windows 7 Ultimate
  - 64-bit operating system
- Wacom Intuos Touch Tablet

Software used:

- Autodesk 3ds Max 2016
- Adobe Photoshop CC 2014
- CrazyBump
- Marmoset Toolbag 2.0

The workflow for the creation of the artifacts for this thesis is as follows.

1. Gather extensive reference material for each of the three weapon types.
2. Create proxy models for each of the three weapon types and the tentative modular attachments. Set units to standard Unreal units where 1unit = 1cm.
3. Use standard pivot in weapon body as a basis for aligning all modular components and do not change this pivot point.
4. Create high poly models for each of the modular models.
5. Create game resolution model for each of the modular models.
6. Create UVW maps for all game resolution models.
7. Bake normal maps onto game resolution models using the information from the high poly models.
8. Create basic textures in Adobe Photoshop CC 2014.
9. Import all models and base texture files into Marmoset Toolbag 2.0 to create materials and review results.
10. Make adjustments to texture files.
11. Repeat step 10 until artifact completion.
12. Render high resolution images of completed weapon archetypes.

B. Process

This thesis begins with the creation of the three base weapon bodies, inspired by the designs of the AK-47 assault rifle, Mossberg 500 tactical shotgun, and the Colt M1911A1 service pistol.

The first part of this project focused on where modular pieces attach to these models as well as how they connect to the model. The schedule allowed one week of modeling time for each of the three weapon bodies to account for time spent adjusting the weapons for modularity. All modeling of artifacts occurred in Autodesk 3ds Max 2016. The beginning models were created alongside a human scale figure in order to keep every model within the size limits for being held by a game character. The approaches taken toward the three weapon bodies differed in a few ways.

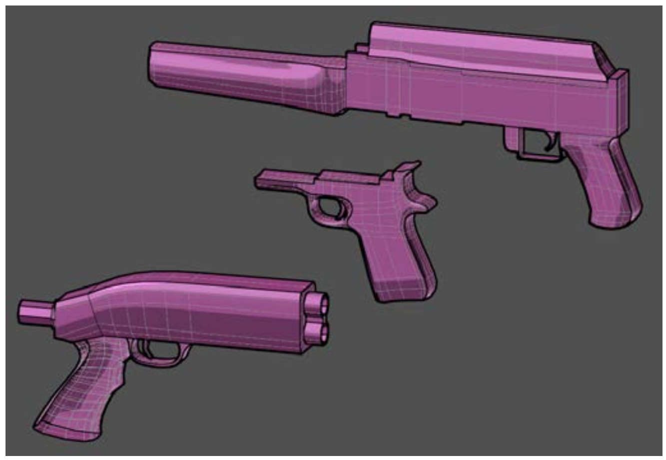

Figure 6: Main weapon bodies blocked out in 3ds Max.

After the completion of the three main body components, modeling of the basic set of modular pieces occurred. This includes a complete set for each weapon type, paying close attention to the modularity points for each piece.

Each set included a trigger and barrel specific to each weapon, as well as a stock and grip that would be modular across the different weapon types. The bodies of the shotgun and assault rifle were created in such a way that each modular piece would snap to a certain area of the weapon by aligning the pivot points, thus allowing proper placements of the stocks and grips. The image below shows the initial placement of the first two stocks and first three grips. Later iteration allowed for the removal of the grip from the body of the pistol to allow for even more modularity between the weapons.

For the assault rifle, initial modeling started as a spline; however, trial and error proved that starting this model as a box was a superior method of creating this specific piece. The shotgun and pistol bodies were completed using a spline modeling method, and finalized by collapsing a surface modifier onto the model in order to cap the open edges. This difference in modeling is due to the inherent shapes of the weapons, with the shotgun and pistol having more curved surfaces than the assault rifle.

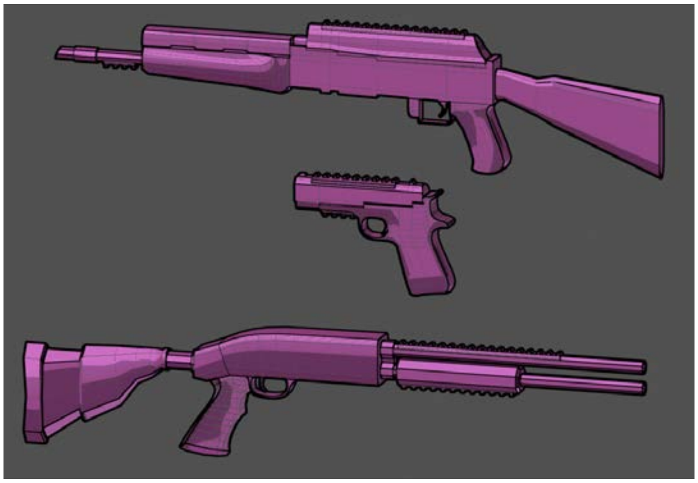

FIGURE 7: FIRST MODULAR PIECES ASSEMBLED IN BASE WEAPON FORMS.

After separating the grip from the model of the pistol and replacing it with another, more detailed grip that would serve as a modular piece across all weapon sets, the next step is to create more of these modular pieces until four of each type of modular component exist. By taking the initial model of a modular component, the process was sped up significantly for the creation of the following pieces. While some of the modular components are altered versions of the originals, the stocks were made individually to match the reference polygon on both the assault rifle and shotgun bodies.

During this phase, it also became necessary to build one distinct magazine for the assault rifle, as the ammunition is not loaded directly into the weapon as the shotgun and pistol are. This did not add much time to the development schedule, despite not having accounted for it as a necessary component in the beginning. It did however, add a much needed component to the assault rifle silhouette. The following image shows the basic mock-up of each weapon, and the interchangeable pieces created during this phase of the project.

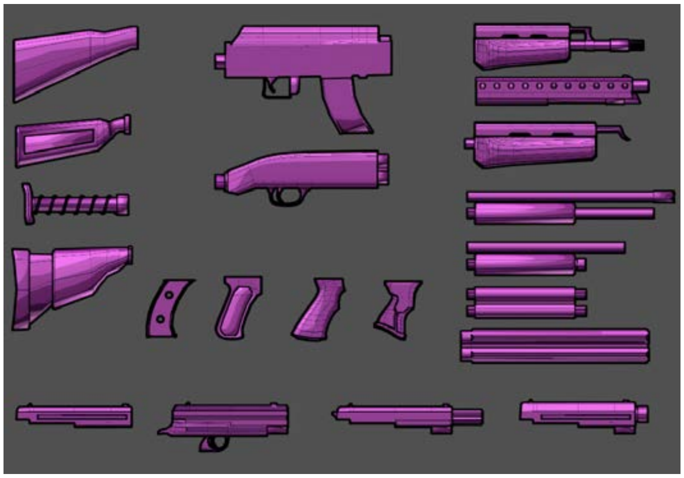

FIGURE 8: ADDITIONAL MODULAR PIECES MODELED AND ASSEMBLED IN RESPECTIVE LOCATIONS.

Each modular component has four interchangeable models, for twelve possible modular weapon components for each base body. The only difference is in the pistol, which has modular barrels and grips, but no stock like the other two weapon types. In addition to these necessary components, the set includes four universal accessories for use on all three weapon types. As the modular components of the three weapons reached completion, a picatinny railing system was created for a logical placement of all four universal attachments.

During this phase of development, the universal attachments were also created. The attachments include a blade, flashlight, scope, and red dot sight. Each of these pieces attach to the weapons using the picatinny rails. Also, to decrease development time, the model of the flashlight was used as a base for creating the scope.

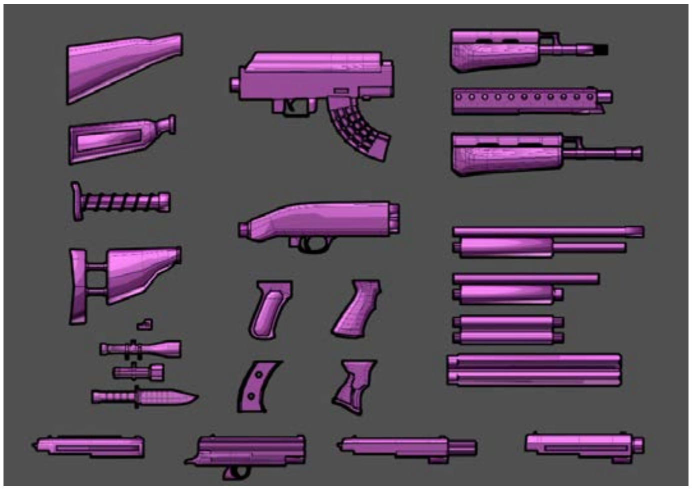

FIGURE 9: LOW POLY MODELS, RENDERED IN 3DS MAX.

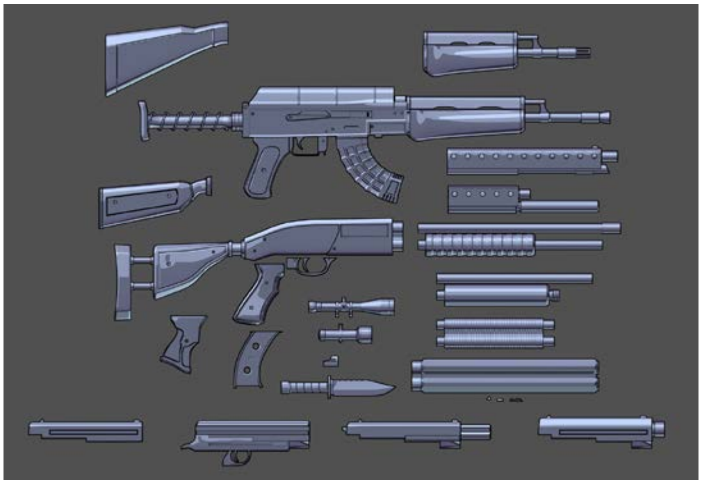

FIGURE 10: HIGH RESOLUTION MODELS, RENDERED IN 3DS MAX.

The next step was to unwrap each game resolution model and bake normal data into the UVW maps using the high-resolution models, using the models show in the above two images. The normal maps for each component were projected individually, allowing for a more comprehensive use of the projection cage in the render to texture menu within 3ds Max. The high resolution models for the overall weapon shapes and main components were all created using 3ds Max 2016. After all components had normal data projected onto them, the individual images were combined onto a single normal map, layering each image in the same Photoshop file and then exporting it as a single Targa image to be used within the game engine as well as a preview in Marmoset Toolbag. Layering the image allowed for easier adjustment of individual normal maps should a component need to be altered in any way and require a new normal map, which a few of them did in the first pass. While the main component normal and cavity maps were created in 3ds Max, the finer details were emphasized in CrazyBump as well as using this software for the basis of an occlusion map.

After completing these steps, each set of modular artifacts needed textures. Using Adobe Photoshop CC 2014 and CrazyBump software, each set of models received a texture for import into Marmoset Toolbag 2.0. The textures the models received include an Albedo, Normal, Cavity, Roughness, and Metalness map. When creating the maps, the main components were combined onto one atlas, a map that contains the data for multiple components using the same texture. The Albedo, Metalness, and Roughness maps were hand-painted in Photoshop to keep all of the shading and details consistent across all of the components. When all maps are completed, the Roughness and Metalness maps are combined into one Targa file containing the data from each map on a different layer in the RGB channels, ultimately creating one detail map for each texture set for use in a game engine.

Figure 11: Textured models, rendered in Marmoset 2.0

When all materials existed within the project in Marmoset, each of the models and textures was divided into sets, and the materials were applied. At this point, the textures were changed and adjusted until the artifact was complete. Completion is defined when all models and textures exist and are organized into each of their respective modular sets, and after assembling a portion of the possible combinations of modular weapons.

After completion of the textures, a screenshot example of each weapon archetype was rendered out of Marmoset Toolbag 2.0 using the Unreal shader. These renders are indicative of a sample base model without any accessories, and include polygon counts of the sample weapons. The renders include a “beauty shot,” a profile wireframe image, and a first-person perspective of the weapon, all featuring the base gunmetal albedo.

Figure 12: Pistol, rendered in Marmoset 2.0

Figure 13: Rifle, rendered in Marmoset 2.0

Figure 14: Shotgun, rendered in Marmoset 2.0

The textures for this project were divided onto two atlases, which are larger texture maps containing multiple components on a single map. One atlas served as the textures for the main gun components and another for the attachments and railing system. Since each of the atlases were hand-painted, it was easier to maintain consistency across all of the modular components, especially for the Metalness and Roughness maps. The following images show each of the maps used for creating the Unreal shader in Marmoset 2.0.

For visual demonstration purposes, alternative albedo textures for the weapon components were saved out as separate image maps, but they were created by using custom painted tiling camouflage textures. In engine, these textures can be used with a black and white mask in the material to minimize the number of materials being used.

Weapon Components:

FIGURE 15: WEAPON COMPONENT ALBEDO MAP

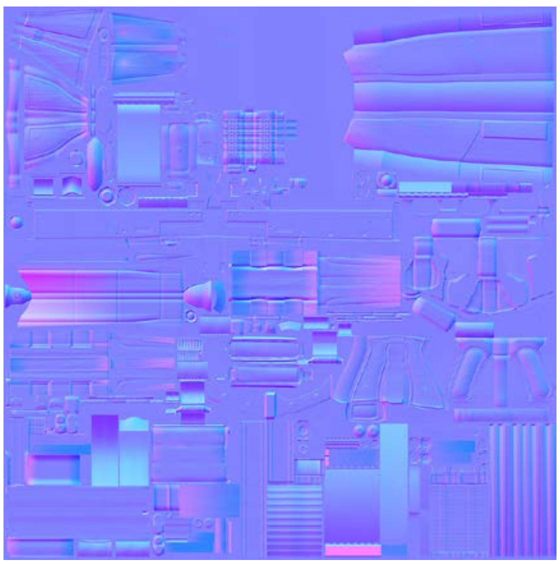

FIGURE 16: WEAPON COMPONENT NORMAL MAP

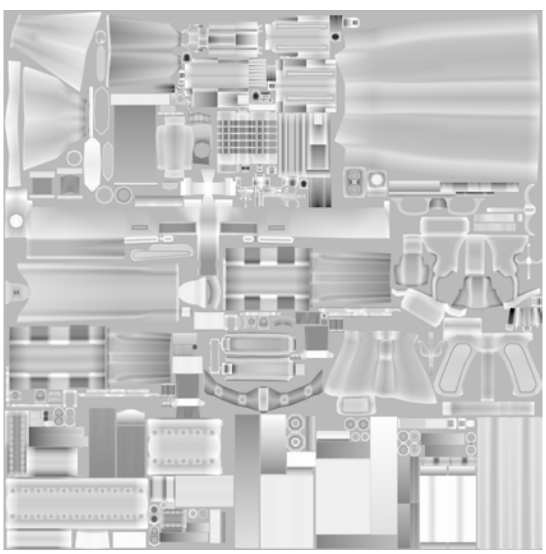

FIGURE 17: WEAPON CAVITY MAP

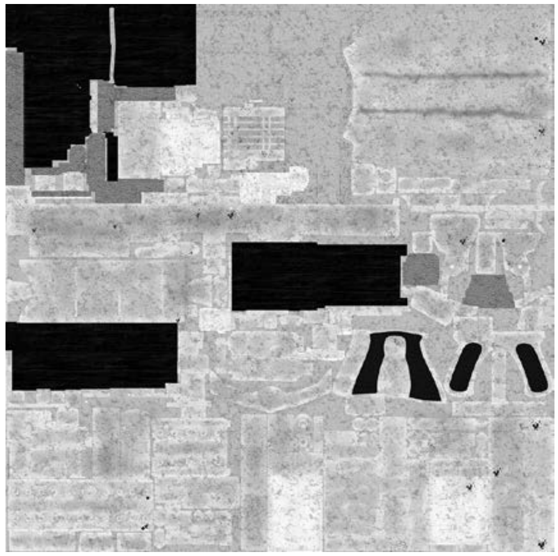

FIGURE 18: WEAPON COMPONENT METALNESS MAP

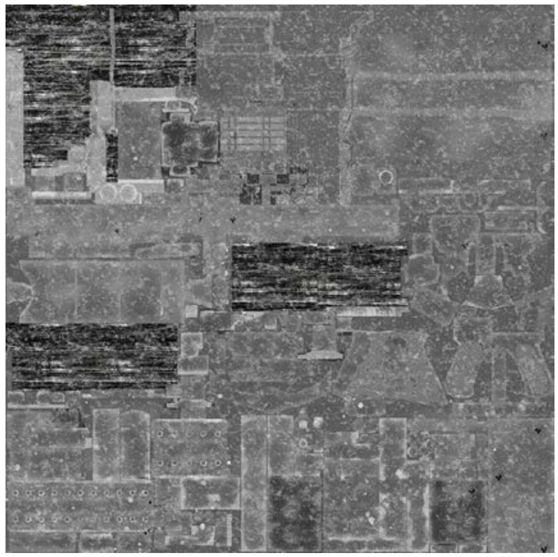

FIGURE 19: WEAPON COMPONENT ROUGHNESS MAP

Attachments:

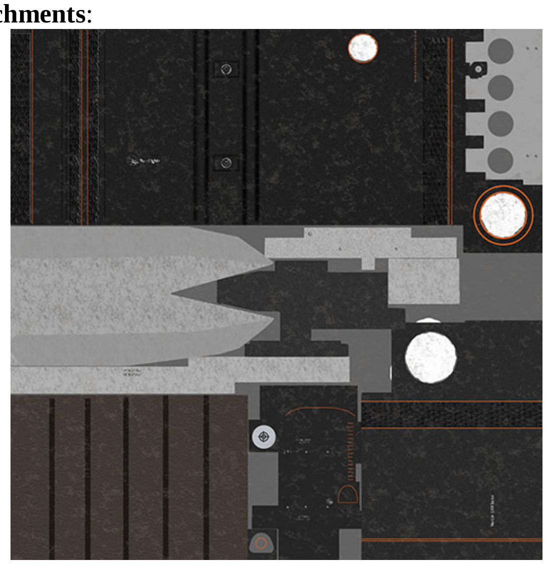

FIGURE 20: ATTACHMENT ALBEDO MAP

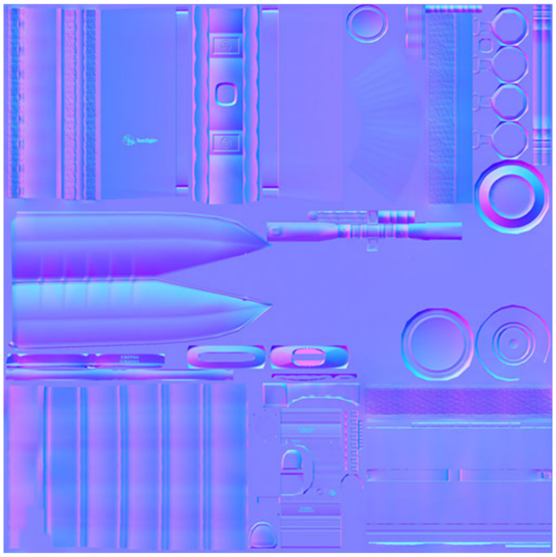

Figure 21: Attachment Normal map

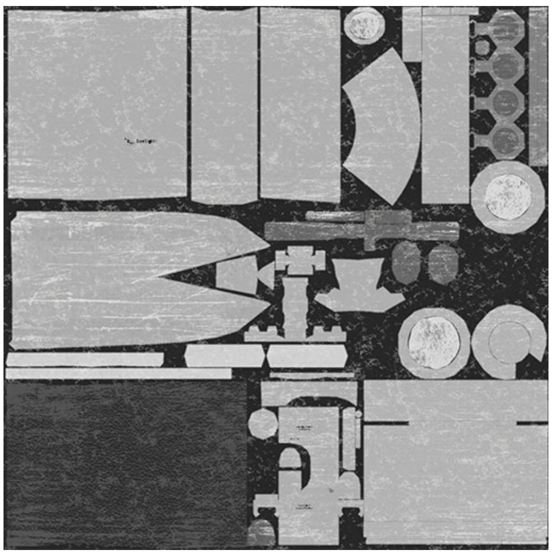

Figure 22: Attachment Metalness Map

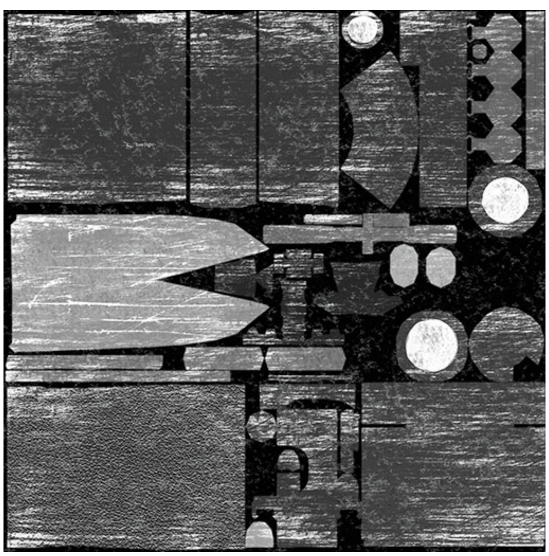

Figure 23: Attachment Roughness map

Alternate Weapons Albedo Maps:

Figure 24: Pistol – Alternate Albedo Maps

Figure 25: Rifle – Alternate Albedo Maps

Figure 26: Shotgun - Alternate Albedo Maps

Figure 27: Rifle with Scope and Blade attachments

FIGURE 28: RIFLE WITH SIGHT AND FLASHLIGHT ATTACHMENTS

IV. CONCLUSION

The purpose of this project was to create a modular system for assembling complete and varied weapon loadouts in a game engine for three different weapon types, including an assault rifle, shotgun, and pistol. Since this was a non-environmental modularity set, different potential risks had to be considered than if the set was for an environment. Each weapon set had their own uniquely fitting modular pieces. In addition, there was a smaller universal set of accessories, to include blade attachments and flashlights. The plan was to build each weapon in succession, beginning with the bodies of each weapon and then the modular pieces for each set in the order that the bodies were constructed. When all pieces were completed, each weapon set received a base texture. Additional textures were added later in the process without interfering with the original timeline. The findings showed that it is possible to create the potential for hundreds to even thousands of weapon variations within a limited time with minimal rework.

Identifying the risks and complications of creating a modular weapon system early was essential to the success of this project. Iteration began immediately after research was complete. Testing of the artifact continued all the way through development, until all modular pieces received approval for texturing. Utilizing the methods and images explained in the weapons patents as well as methods used currently in games proved very useful for this type of project when aiming for realism and believability.

What went well during this project was that the system functions as it is supposed to, and creates 9,216 different weapons using a set of 30 total modular pieces and four material options. This is mainly because I did not deviate from the points of reference for the weapon types. Keeping the consistency across the modular pieces was the highest priority, and took the most amount of time. Also, once an example modular piece was built, additional pieces could be created much more quickly than the first. This allowed for more iteration time on the types of modular pieces as well as more options when making choices about which to refine further.

A few complications that arose during this development process include the locations of the grips across the different weapon types, the time it took to create a working system, and rework on the accessories late in development. The grips proved to be a challenge because each weapon archetype is radically different in size and shape. The grips had to fit the pistol first, which was the narrowest of the weapons. Also, the grips sat at different places across the types. A solution I found for this is to set up a custom location in each archetype's respective blueprint in a game engine. Secondly, I greatly underestimated the time it would take to create this type of modeling system for weapons, which significantly slowed down development in the beginning. However, after refining the process and re-assessing the priorities for the system, I was able to quickly build additional modular assets. Lastly, due to the normal maps not behaving the way I intended, I had to go back and add more polygons to the cylindrical accessories for them to appear more round, especially if viewing them from a first-person perspective. This only added a little bit more time to development, but it is time that could have been spent refining other things had this problem been foreseen earlier. Despite these setbacks, I was able to make up for time lost to complete this system.

What I found to be the most important takeaway from this project is that defining the parameters and dimensions of the pieces should take the highest priority in the beginning, and once the point of reference is completed, not to deviate from those parameters. I also learned that though creating a modular modeling system for non-environmental assets takes a significant amount of time in early-production, it speeds up the creation pipeline later in development should more pieces be necessary or desired. When the system begins to work as intended, it creates the potential for thousands of weapons, whereas standalone modeling could develop only a tiny fraction of that number in the same amount of time.

Further research into this subject could include creating more attachment types for the various weapons, finding additional ways to connect the weapons to combine them into new types, and more variations of the modular components. The textures created for this project show the ease of swapping materials for a greater sense of customization. Should more time be spent on this project in the future, it would provide a great basis for use in blueprint systems in Unreal Engine 4, in which multiple disciplines would be able to use the modular pieces to create different weapons without dragging individual pieces into the scene. The same process could be used for a weapon customization interface, in which a player could change out the parts in a menu screen. This system also has the potential for usage across other genres, including but not limited to sci-fi and fantasy games. This modeling system could be utilized for the creation process of ray guns, armor sets that have upgradeable parts, swords and other medieval-styled weaponry as well as mages staffs. Though the process would have to be modified based on the type of object being modeled, the same principle guidelines outlined here serve as a good basis to start from.

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T. L. Griffith is a graduate student at the Guildhall at Southern Methodist University, Plano, TX 75024 USA (e-mail: tlgriffith@mail.smu.edu). Her previous works include two PC titles, The Abyss (2D side-scrolling shooter) and Scrapped (3D platformer). Tiffany received her B.A. from Gonzaga University majoring in Fine Art and Psychology.

B. Fisher is a professor at the Guildhall at Southern Methodist University, Plano, TX 75024 USA (e-mail: bjfisher@mail.smu.edu). He is a seven year veteran of the game industry with five titles under his belt. He has developed on different platforms, from arcade to console, PC and mobile. These include F.E.A.R. 3, the Avengers Initiative and Superbikes. He joined the Guildhall in 2013 where he teaches content creation for games and helps students develop a modular way of thinking and problem solving ability. Boris received his B.F.A. from the Illinois Institute of Art majoring in Media Arts and Animation.

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