DEVELOPING A PRODUCTION PIPELINE FOR PAPERCRAFT BLENDING PEPAKURA & 3D UNWRAP-UV TEXTURING TECHNIQUE

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This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Multimedia and Creative Technology

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DHAKA, BANGLADESH

MARCH 04, 2023

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APPROVAL

This Project titled "**Developing A Production Pipeline for PaperCraft Blending Pepakura & 3D Unwrap-UV Texturing Technique**", submitted by Mehedi Hasan Roby to the Department of Multimedia and Creative Technology, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Multimedia and Creative Technology and approved as to its style and contents. The presentation has been held on 4 March, 2023.

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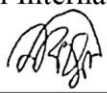

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I hereby declare that, this project has been done by me under the supervision of **Arif Ahmed, Associate Professor, Department of Multimedia and Creative Technology,** Daffodil International University. I also declare that neither this project nor any part of this project has been submitted elsewhere for award of any degree or diploma.

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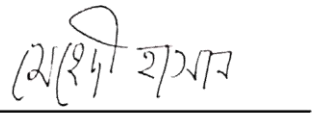

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ACKNOWLEDGEMENT

First, I express my heartiest thanks and gratefulness to almighty God for His divine blessing makes us possible to complete the final year project successfully.

I really grateful and wish our profound our indebtedness to **Arif Ahmed**, **Associate Professor**, Department of MCT Daffodil International University, Dhaka. Deep Knowledge & keen interest of our supervisor in the field of "3D visualization" to carry out this project. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts and correcting them at all stage have made it possible to complete this project.

I would like to express my heartiest gratitude to Dr. Shaikh Muhammad Allayear, Professor, Department of Multimedia and Creative Technology, Md. Salah Uddin, Assistant Professor & Head (In-Charge), Department of Multimedia and Creative Technology & Mizanur Rahman, Assistant Professor, Department of Multimedia and Creative Technology, for their kind help to finish my project and also to other faculty member and the staff of MCT department of Daffodil International University.

I would like to thank my entire course mate in Daffodil International University, who took part in this discuss while completing the course work.

Finally, I must acknowledge with due respect the constant support and patients of my parents.

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ABSTRACT

The projects aim to create a production pipeline for papercraft from 3D models. From children's toys to teen action figures, a booming industry has been growing worldwide. Most of the figurines available commercially are pretty expensive, especially collectible action figures. Moreover, majority of these products are made of plastic and other non-biodegradable materials, thus also not eco-friendly. The aim of the project was to create a more affordable, environment-friendly and interactive paper models that consumers can buy to make their own paper figurines.

The entire project was created using CGI (computer-generated imagery) technology. The project involved steps to prepare a template for 3D paper models such as unwrapping and texturing for papercraft layouts. RizomUV was used to unwrap an available 3D model, followed by texturing using Substance Painter. Pepakura Designer 5 was then used to design a 2D design layout that can be printed, cut and folded to create a 3D paper model in real world.

The outcome of the project can create mass-producible papercraft layouts that can be created by consumers through interactive instructions. In future, the project can be used for stop-motion and movie props as a better alternative for conventional materials.

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CHAPTER 1: INTRODUCTION

1.1 INRODUCTION

In this section, introductory review of the project is described. The whole project report has been divided into several sections, including the fundamental idea of my project, inspiration that driven me to do this and the goal that I want to achieve through this project, followed by the objectives and workflow to achieve the goal.

1.2 MOTIVATION

Paper crafts are age old forms of art that employ paper as the preliminary artistic media to create three-dimensional objects. Card stocks and papers can be folded, cut, bent, curved, layered or molded through a wide range of techniques [1]. There are many variations within the paper art. Some common paper craft forms include:

01. Origami

02. Quilling

03. Kirigami

04. Painted paper collage

05. Decoupage

06. Paper mache

07. Paper Marbling

Among the many forms of paper craft, Origami was my center of interest, and thus my topic of this project was inspired from Origami. The motivation behind this project was to produce a workflow to create three-dimensional paper model from 3D design, so anyone can prepare and create paper models from their own imagination.

The Japanese word "origami" is made up of the smaller words "ori," which means to fold, and "kami," which means paper. Origami is the Japanese art of folding single sheets of

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paper into decorative figures. In modern days, the term "origami" is often generalized as an umbrella term for all paper-folding practices, regardless of their source or origin. It involves transforming a flat square sheet of paper into a sculpture through folding and sculpting techniques [2]. Traditionally, these designs begin with a square sheet of paper whose sides may be of different colors, prints, or patterns.

Figure 1.2: Origami Paper Crane (Tsuru) by Icarus Mid Air [3]

Types of Origami:

1. Action origami: In addition to the more common still-life origami, there are also moving object designs; origami can move [4].

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2. Modular origami: Modular origami consists of producing identical pieces that are subsequently pieced together to form a complete model. Although the individual pieces might be simple to make, the final assembly may be difficult to achieve [5].

3. Wet-folding: An origami method called wet-folding creates structures with smooth curves rather than the typical geometric straight folds and flat surfaces. This is achieved by wetting, folding and drying the wet paper to fix the structure with curves that imitate a more lifelike pattern [6].

Figure 1.2: Wet-folding Origami by Hoang Tien Quyet [7]

4. Pureland origami: Pureland origami involves the restrictions that only simple mountain/valley folds are to be used, and all folds must have straightforward locations [8].

5. Origami tessellations: Since 2000, the practice of origami tessellation became increasingly popular. Instead of a model or figurine, a group of figures that

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occupy a plane entirely and without overlaps is known as a tessellation. In origami tessellations, pleats are used to connect units such as twist folds together in a repeating fashion, creating an intricate pattern with a single sheet of paper [9].

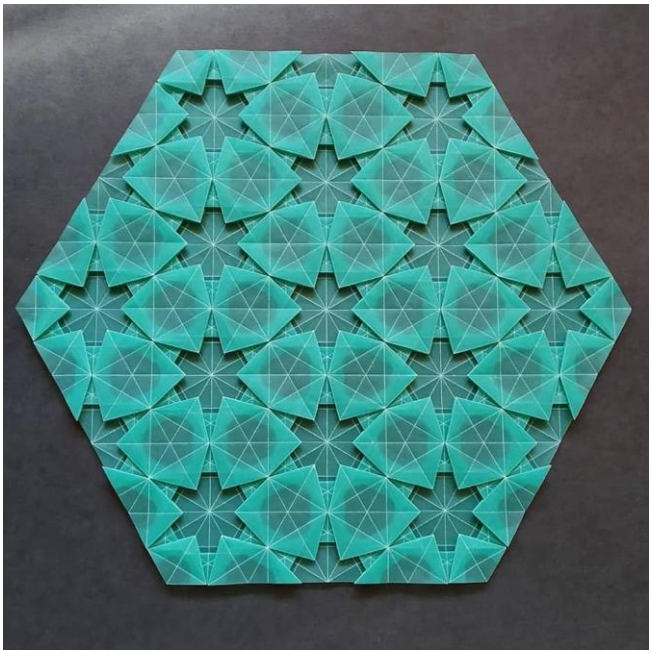

Figure 1.2: Tessellation Origami by Alessandro Beber [10]

6. Kirigami: Kirigami is a Japanese term for paper cutting. This form of folding exclusively involves models with cuts. In contrast to traditional origami, kirigami involves cutting paper to achieve the final result. [11].

7. Strip folding: Strip folding is a combination of folding and weaving paper strips. It is also called “origami fringe” [12].

8. Teabag folding: Teabag folding is credited to Dutch artist Tiny van der Plas, who developed the technique in 1992 as a papercraft art for embellishing greeting cards [2].

1.3 RESEARCH OBJECTIVE

Computer aided design can be useful, creative and interesting because it allows user to carefully model, create and manipulate all aspects of a shape even at the smallest of scale to imitate reality and movements.

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3D modeling is a subset of CAD (computer-aided design) that involves using software to create three-dimensional representations of a figure, surface or original item. In general, 3D modeling improves the authenticity and efficiency of product designing. One may perform the following using 3D modeling programs:

- Visualize final images before production
- Make alterations and improvements to the designs.
- Design, materials, and dimensions can be documented easily.

3D modeling is essentially the first step in the 3D printing process. [20]. Once the perfect model virtually built, the aspect to create a similar reality object comes to light. This has been made possible by CNC (Computer Numerical Controlled) machines for decades. These machines carve the shape from a solid block unit of material. Modern upgrade in this department is 3D printing which does a similar job to an Inkjet printer. But rather than ink, layers of melted plastics are placed on top of one another. Since 2005, the Replication Rapid Prototype (REPRAP) project initiated by the University of Bath (UK) made 3D printing available to hobbyist community throughout the world. Today, a REPRAP printer costs 500-1,500€ to build or buy a commercial one.

Three-dimensional (3D) printing involves manufacturing process in which a physical object is produced from a digitally generated design by printing thin layers of material (like plastic) and then fusing the layers together. Some industries use 3D printing to create industrial prototypes and mass produce their products using custom scans, such as hearing aids and car manufacturers. 3D printing allows printing of more complex designs than traditional manufacturing processes with ease. Most traditional processes have design restrictions that do not limit 3D printing [21]. The technology can be used to repair toys, create spare parts, or create customized items like figurines or even transplants. While it is currently not as efficient for mass production, 3D printing technology is gradually evolving and has the potential to change the interface of both the manufacturing logistics and inventory management industries [22].

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Figure 1.3: 3D Printing Models [23]

While a variety of metals and polymers may be used to construct objects using 3D printing, the range of raw materials is not completely diverse. This is due to the fact that not all metals or plastics are easily manipulated by temperature to allow 3D printing. In addition, many of these materials might not be recycled and very few are safe for consumption and environment. PLA and ABS, the two most common types of plastics used for printing purpose are expensive and toxic. 3D printing also poses as a threat to environment. Materials like PLA can release particulates and other harmful chemicals into the air. Users can also get exposed to hazardous materials, such as metal powders, microparticles, solvents and other chemicals. It's also not a cost-effective method for massive production, as 3D printers themselves are expensive.

3D printers currently have confined print chambers with restrictions on the size of parts that can be printed. Anything bigger that restricted limit will need to be printed in separate parts and joined together after production. This can affect the production by increasing costs and time for larger parts, and manual labor is needed to join the parts together.

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Another issue with 3D printing is pos-processing. The majority of 3D printed items require human cleanup to remove support material, smooth the surface, and obtain the desired quality. Such methods include sanding, chemical soak & rinse, water jetting, air or heat drying and assembly. The amount of post processing required to get the finished product depends on factors such as the size of the parts, the printer itself, raw-materials, the intended application and the technology of 3D printing used for production. So, while 3D printing allows faster production of parts, post-processing may slow the speed of manufacture [24].

In contrast, two-dimensional printers use readily available, conventional materials like ink and paper for the production operations. Preparing a 2D printable template from a 3D model with textures can be printed and easily folded and assembled to create a 3D paper model in the real world. It's an eco-friendly & less time-consuming production process than 3D printing.

The application of 3D modeling greatly assists in the designing and construction of paper models from digital sources. The source in question, for example, a video game, will have to be loaded into the computer. Several techniques can be used to extract the model, such as directly capturing it from the simulation or exporting it from a model viewer into a useful file format. The methods of extracting the model are often selective for the subject and the tools available. Readability of file-formats including propriety ones could mean that a model viewer and exporter is restricted for the developer. Thus, using other tools to capture rendered 3D models and textures is often the only way to obtain them. In this case, the textures and the wireframe model might have to be arranged on a 3D program, such as 3DS MAX, SketchUp, Metasequoia, or Blender before exporting it to a program designed for papercraft model design generation, such as Pepakura Designer by Tama software or Dunreeb Cutout. From there the model can be refined to generate proper layout and construction tabs that can affect the overall construction process and final appearance of the model [13].

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Paper crafts generated by Pepakura program takes a 3D model and flattens it to get a 2D template that can be printed, cut, trace on either foam or just use the printed paper and construct a 3D model physically. Pepakura is originally designed for paper crafting [25].

Paper is an underrated and underappreciated medium in multimedia technology. Many people enjoy developing models out of paper. Rather than just for showing printed information, paper can also be used for constructing physical paper models from virtual objects by means of glue and scissors. The availability of rich 3D model libraries of makes it desirable to automate this task. This requires generation of a planar cut-out sheet from a 3D model. The challenge is to produce a template that divides a given model into simpler, engaging parts that can be approximated by developable surfaces, thus having the property that they can be unfolded in a plane without being creased, stretched or torn. This type of designing can be used in similar applications including textured atlas generation and model production from sheets of material [26].

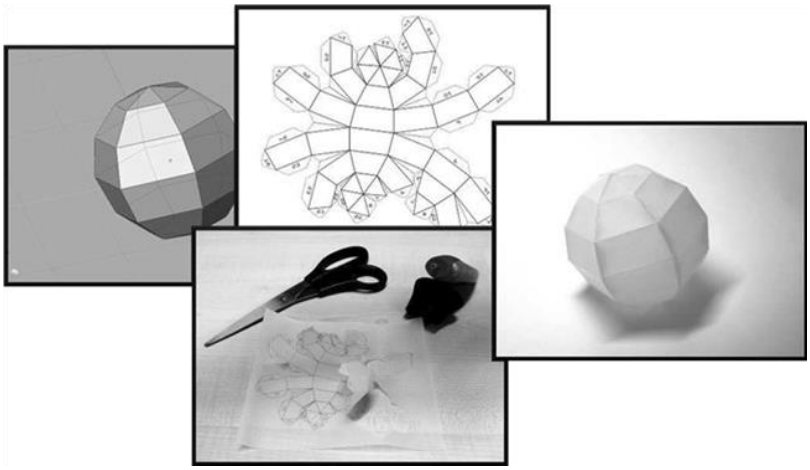

Figure 1.3: Papercraft modeling starts with a virtual 3D model [27]

However, faces forming a model in 3D pose an issue upon unfolding. While 3D space has potential for a non-intersecting topology of faces, they tend to intersect easily in the planar projection of the cut-out sheet. Moreover, neighboring faces enclose such a close angle that it becomes difficult to cut out and glue together. Unfolding a virtual model requires selection of which edges of a 3D model to cut first. A carefully chosen order can

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be helpful to avoid the above-mentioned issues in many cases. However, finding the optimal order is an NP-complete problem.

Large objects can be made with little effort using a simple printer, good quality paper and some glue. Paper models are popular for scale models of architecture, engineering disciplines, industrial design and other applications such as stage props, or production props where a small number of custom-made shapes are needed. Even in the virtual world, many users prefer to own a real 3D paper model of their avatar. To enhance structural integrity as paper models are fragile by nature, they can be reinforced with resin or fiberglass or carbon fiber to create a more durable structure. Fibers are applied inside to preserve the flat surface of the model as well [27].

The following requirements should be met for making paper-craft models:

Approximation of each part by a developable surface.

Ease of cutting and gluing between the boundaries of these approximations.

Minimization of errors defined as a function of the difference between the original model and its paper-craft model.

Minimal number of parts.

Over the last decade, many methods have been proposed and developed for designing such segmenting meshes [26].

1.4 RESEARCH QUESTION

One of the most crucial components of research work is choosing the proper starting point. We encountered various crucial questions from data collection to the paper's conclusion, including

Q.1 How will this study assist people?

Q.2 How will this study serve the industry?

Q.3 How much will people understand the value of 3D-based paper modeling?

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1.5 EXPECTED OUTCOME

Although some paper modeling templates are available over the internet, they are very limited, produced and patented by certain artists and not accessible to everyone. The work process to create a unique design to produce a 3D paper model is not disclosed by majority of the artists, so it poses as a problem if one wants to create something on their own. To overcome this problem, my project focused on unveiling the pipeline to produce a 3D paper model from a design, which can be followed to make customizable, unique models.

1.6 TARGET AUDIENCES

3D paper models can be a useful tool for learning as well as creative implementation. Target audience of this project includes-

1. Interactive toys for kids: paper folding to create their own 3D action figures that could aid the cognitive development of children.

2. Collector's exclusive figurines: 3D figurines of favorite characters can be exclusively designed and produced for collection.

3. Stop-motion props: Creating paper models can be an affordable alternative to conventional props used in stop-motion animation films.

4. Artists who want to create their own designs: The pipeline to create a 3D paper model would encourage artists to materialize their artistic views into reality.

1.7 REPORT'S LAYOUT

For the purpose of presenting my work, this report is one of five distinct components. Each component of this paper is subdivided into a few sections, which makes it simpler to understand.

Chapter 1: Introduction, it's the first section. This will enable it simpler for the reader to understand exactly what it is we will actually look into throughout the test. This section also outlines the study question, aims, and anticipated results.

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Chapter 2: Background, demonstrates the framework for the examination. earlier relevant studies were covered in this section. The divide between current work and related work is another thing we look at.

Chapter 3: Research Methodology, we'll talk about the procedures and software needed for my workflow in this part.

Chapter 4: Experimental Result & Discussion, the experimental outcomes and analysis of our study are covered in here.

Chapter 5: Conclusion and Future Scope of Work is the last part of this report. Here, we discuss the conclusion of the project, its summary, our limitations, and how we should approach this task going forward.

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CHAPTER 2: BACKGROUND STUDY

2.1 INTRODUCTION

In this chapter, we'll talk about paper models, their development over the years, as well as all the alterations that have occurred in between those changes. Regarding the magnitude of our issues what obstacles we would encounter in order to achieve this.

2.2 LITERATURE REVIEW

Paper models also known as card models or paper figurines are models that are mostly made out of thick sheets of paper, cardboard, card stock, or foam. This may be considered a broad category containing card modeling and origami. To compare, Origami is the process of making a paper model by folding a single piece of paper without using glue or cutting, while card modeling is making scale models from sheets of cardstock on which the parts were printed, usually in full color. To assemble these parts, the design would be printed, cut out, folded, and glued. Paper modeling involves designing complex creations such as life-size characters, wearable armors, and weapon models. [13].

Figure 2.2: Paper Action Figurine [14]

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The first paper models are dated back to 17th Century Europe, and earliest records of commercial models were found in French toy catalogs during 1800s [15]. Printed card became common in the early 20th century. Called Paper-Card Modeling in Europe, it ranged from simple darts to complex miniature models of airplanes, ships and buildings.

During World War II, materials were in supply shortage, and those that were available had restrictions of use. As necessity listed, toys were found at the bottom of the list. During this crisis, the U.S. toymakers decided to switch to toys and games made of paper and other nonstrategic materials. Even then, bizarre-colored paper models were produced due to shortages of printing ink.

History of paper-model names an Englishman called Wallis Rigby. He moved his company to United States during the late 1930s with his company. Famous for his airplane, boat and train models made out of paper before WWII, he invented the Tab-and-Slot construction, which gained much publicity during the wartime. Since toys made of nonstrategic materials were on demand, Rigby's paper models gained more attention and were subsequently published as boxed sets and individual books. Moreover, individual aircraft models like Douglas Dauntless were published in newspapers in the colored Sunday Comic Section. Popularity of such products led to media coverage of Rigby, who demonstrated the steps in designing, building and flying his paper-model aircrafts.

The impact of a material scarcity on premiums was also felt by cereal producers. General Mills offered simplified paper airplane models as cereal prizes in 1944, emulating Rigby's designs. Mail in two box tops from Wheaties cereal and you received a pair of paper airplanes. Thousands of these models were distributed by General Mills as part of a nationwide competition. Backing this was a publicity campaign, showing Veterans in hospitals building the models. A contest held at Nebraska's Boy's Town garnered national Newsreel coverage, too. Several children and adults first tried model construction using paper airplanes.

Following WWII, once the restrictions were lifted, usual materials like metal, wood and even newer plastics replaced the paper models rapidly for their longevity and appeal. Soon, paper-models disappeared from the U.S Market, and only a limited number of

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publishers continue to print paper-models [16]. Similarly, Micromodels [17], designed and produced in England from 1941 were very popular with over a hundred different models, including aircrafts, architecture and ships [18]. But as plastic models [19] became more commonly available, interest in paper-models decreased in competition.

2.3 SCOPE OF THE PROBLEM

Our nation's technological development is quite far behind that of other third-world nations. On the other hand, in countries like the USA, UK, China, Japan children are more advanced in technology. They got introduced to 3D modeling and printing at a very early age from their schools. With the help of 3D printing, they are having the ability to make a variety of entertaining crafts and interactive toys. This is how they develop an early interest in 3D.

Compared to children in other developed countries, children in our country are not very familiar with 3D technology. Because these 3D printing machines and their components are quite expensive. In contrast, paper and 2D printers are widely available and cheap in our country. 2D printers are available in most of our schools, colleges in our country nowadays. So, these 3D base paper figurine toys can be a good alternative for the school children to increase their interest in 3D.

2.4 CHALLENGES

I had to overcome a number of obstacles during my studies in order to complete my research. The hardest part was that I couldn't identify enough literary works that related to my study topic. Second, figuring out the workflow was extremely difficult since there are very few paper modeling templates available online, they are made and trademarked by certain artists, and they are not available to everyone. The majority of artists don't reveal their creative method for producing original designs as 3D paper models, which presents a challenge for anyone looking to build anything on their own.

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CHAPTER 3: PROPOSED RESEARCH MODEL

In this chapter, I will outline my study topic and the approach I employed to achieve my goal.

3.1 RESEARCH AREA & CONSTRUCTIONS

I had to choose the techniques I wanted to use in my process before I could set up my pipeline. Before jumping into my experimental process, I studied my methods and materials. These are the following research are & contractions I've found related to my work:

1. 3D UNWRAP-UV TEXTURING

A UV map represents the flat surface of the 3D model used for texture wrapping. Using 3D modeling software, a procedure known as UV unwrapping produces a UV map. The letters U and V in UV mapping refers to the axis of the 2D texture in the UV grid, where X, Y, and Z are used for the axis of 3D objects [28].

Figure 3.1: UV Mapping & Texturing [29]

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Texturing is another crucial stage of 3D modeling process. Texture can be defined as an image that is being projected on a flat surface of 3D object that gives the impression of a real object. This includes the subtle features of characters seen in 3D models, like wrinkles, hair strands and threads. These are products of textures applied by a 3D artist. Texturing can be explained as something similar to clothing a 3D model. Wrapping a 2-dimensional image around a 3-dimensional item and determining how lighting will affect it is 3D texturing. It is also known as PBR or Physical based rendering [30].

2. PRINTER

A printer is a machine made to take text and visual output from a computer and print it out on paper. Printers vary in size, speed, specificity, sophistication and cost [31]. 3D printing is the process of creating a 3D object from some material instead of paper, like plastic. In contrast, 2D printing simply refers to process of producing an image on paper. Both processes seem to be different. However, the technical operations behind both types of printing have some strong resemblances [32].

There are six different kinds of printers. A3 printers, laser printers, LED printers, dot matrix printers, continuous ink printers, solid ink printers, and inkjet printers are among them. The most common and most used in the market are inkjet printers and laser printers. Inkjet printers are typically sold for day-to-day household use, while laser printers are often used for businesses purposes, but both can be used in either environment [33]. Inkjet printers reproduce a digital image command by spraying ink onto paper. These are the most common and popular types of personal printers. In comparison, Laser printers are used to produce higher-quality prints using laser beam. It involves passing a laser beam at high speed over a negatively charged drum, which defines an image. Color laser printers are usually found in professional settings [34].

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Figure 3.1: 2D Printer [35]

3. TYPES OF PAPER

For paper modeling, different papers are available and artists chose them according to their need. Examples include magazine paper, A4 offset paper, photo paper, inkjet paper, card paper and jasmine paper. Outcomes may vary based on paper and printing process used for the production.

Different types of papers are sold at different market value. Recent view of paper market in Bangladesh is enlisted as below:

A4 print cost 15-25tk/page

A4 Inkjet 25tk/page

A4 Photo paper 30tk/page

A4 Magazine paper 25tk/page

A4 Card paper 30-35tk/page

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3.2 RESEARCH METHODLOGY

The software I utilized for my research methodology are listed below:

1. **AUTODESK MAYA**

Autodesk Maya, or Maya in short, is a 3D computer graphics application that was originally developed by Alias. Currently owned and developed by Autodesk, Maya runs on Windows, macOS and Linux. It is used for interactive 3D applications, animated projects and visual effects [36].

Figure 3.2: Logo of Autodesk Maya

2. **RIZOM UV**

RizomUV is a dedicated UV mapping application with specialized strength for speed of workflow. It is more efficient than its peers, able unwrap, pack, and optimize in seconds. This effectively reduces the hours artists have to spend UV mapping in other applications into minutes [37].

Figure 3.2: Logo of RizomUV

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3. SUBSTANCE PAINTER

Substance Painter is a dedicated 3D painting tool that can be compared as the 3D version of Adobe Photoshop for digital painting work. The main feature of Substance Painter is to texture modeling. It provides advanced masking and procedural texturing tools which allow creating textures that are much more difficult to achieve traditionally using purely 2D program like Photoshop [38]. The software is widely used in games and film visuals, as well as architecture, product design and fashion [39]

Figure 3.2: Logo of Substance Painter

4. PEPAKURA DESIGNER

Pepakura Designer is a Windows application designed to make unfolded patterns from data of a 3D model. Pepakura Designer can automatically unfold 3D polygon-mesh models, and allow user to edit them to produce printable templates. The software is used to create real paper craft model templates from digital data [40].

Figure 3.2: Logo of Pepakura Designer

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CHAPTER 4: EXPERIMENTAL RESEARCH & DISCUSSION

In this chapter, I'm going to give a complete description of my final project that I made for the final defense where I practically show my work method to complete this project. I've used two types of methods here. I'll show step by step how one can prepare a paper model layout from a 3D model

Before starting this project, I researched about low poly and high poly modeling, how to UV Unwrap, how to texture, which method to choose, etc. Then I had to know what type of 3D model is suitable for my project. When it comes to 3D modeling, models can be categorized as either organic or hard surface. Whatever we design in a 3D application will either be a hard surface or an organic mesh [41]. Hard Surface models are best kind of models for paper modelling. But we can do also with organic mesh with low poly count.

So, for this project, my pipeline will be:

- Modelling
- UV Unwrapping
- Baking texture maps
- Making 2D unfolded patterns from 3D data

4.1 EXPERIMENTAL METHODLOGY

Before jumping into Pepakura Designer I first tried to create a layout using only Autodesk Maya and Substance Painter to understand the 2D layouts and what kind of problems I might face in combining them.

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In Autodesk Maya first, I used polygon cube to start making my model. My target was maintaining the low poly count as much as possible.

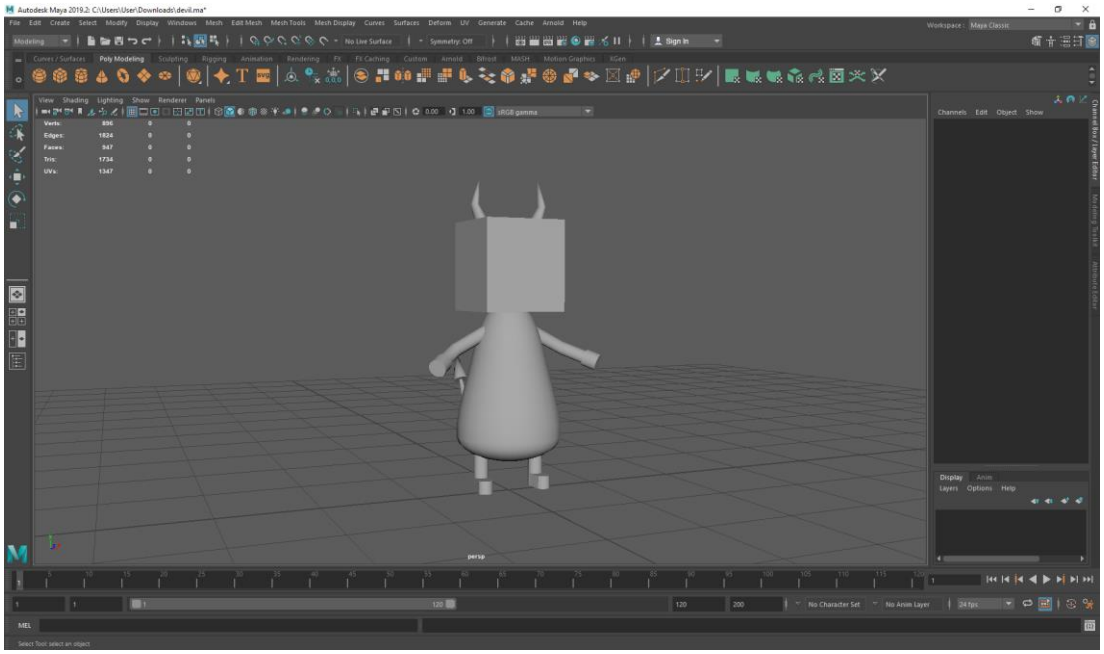

Figure 4.1: Polygonal cube to the model

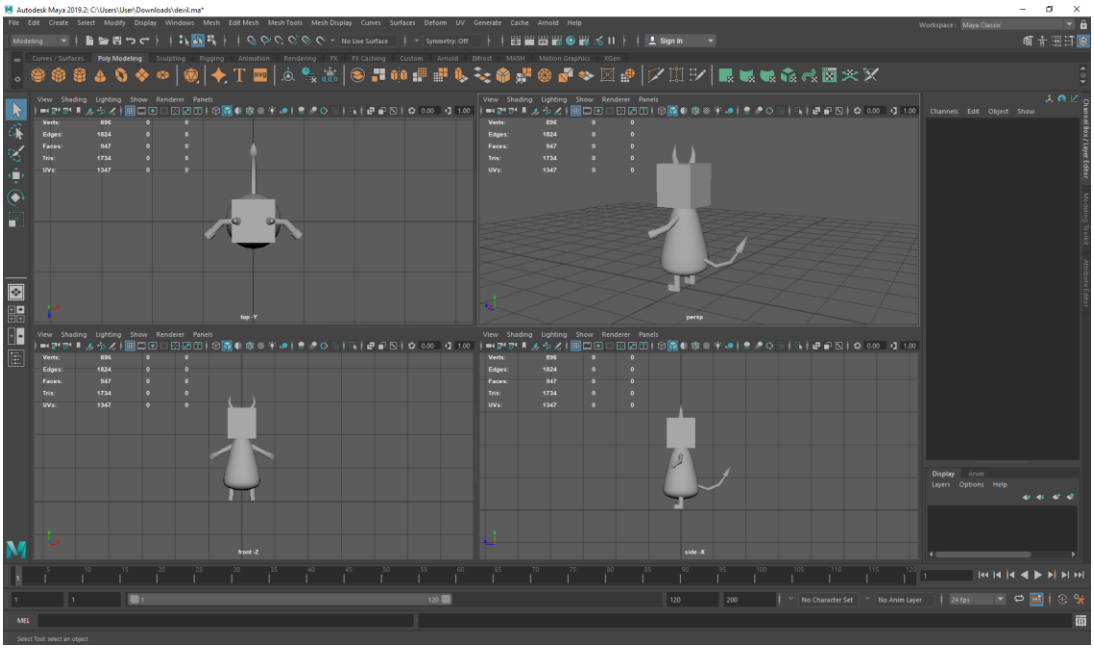

Figure 4.1: Model from four panel view

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After finishing my model, I unfolded my model by clicking the Unfold button in the Unfold section of the UV toolkit.

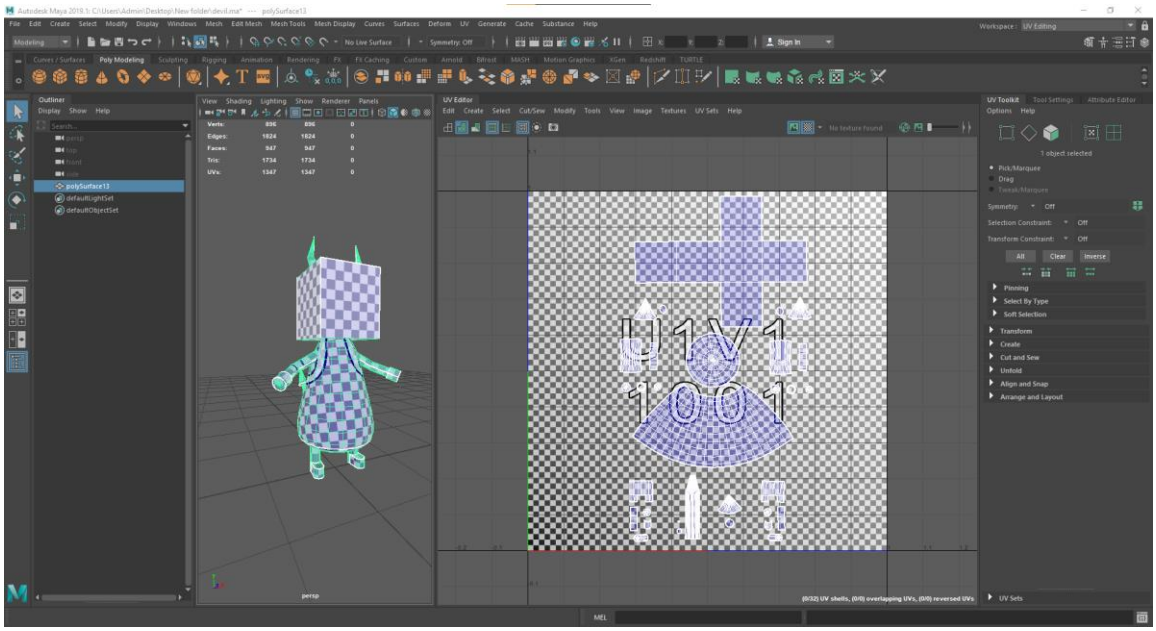

Figure 4.1: UV Unwrapping process of the model

After creating the UV mapping, I import my model into Substance Painter to create the texture map.

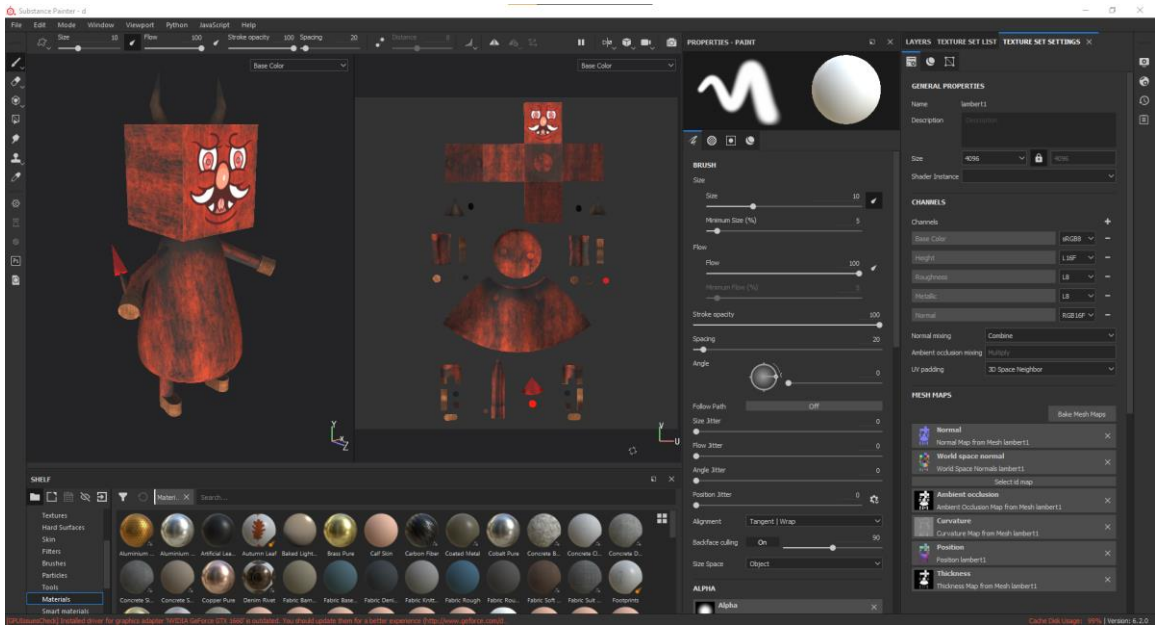

Figure 4.1: Creating texture map in Substance Painter

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I added edge padding to spread the colors outward, creating a border of the same color around the UV shell. So that I can use those padding edges as flaps for my paper model. Then I baked 2D view texture to be used as may paper model layout.

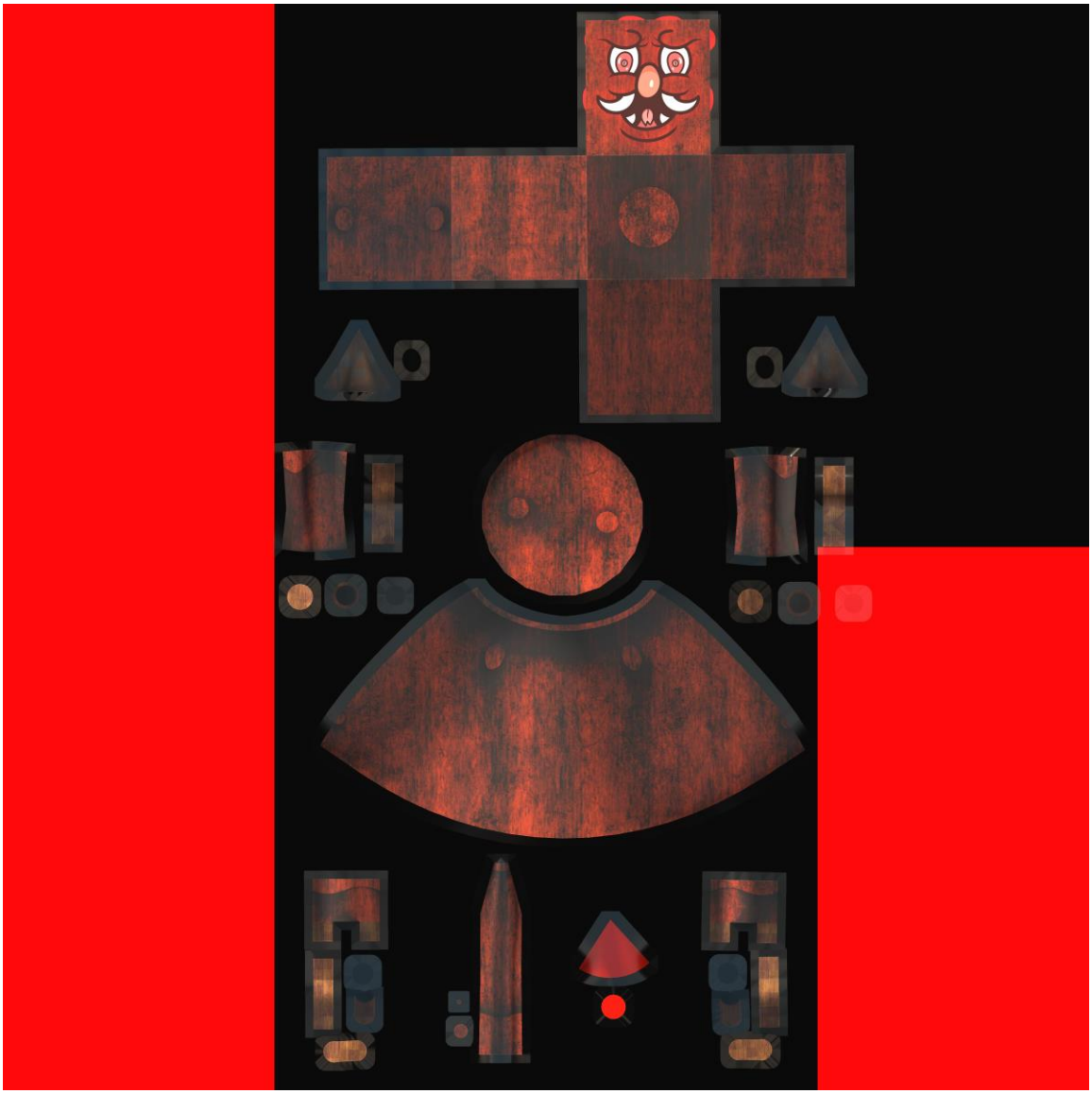

Figure 4.1: Baked 2D view texture

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After that I printed out the 2D texture layout into an A4 size paper and cut out the edge lines and folded the different pieces and glued them together to form the 3D shape of the actual model. This wasn't the satisfactory result I was expecting, so I tried to find other methods.

Figure 4.1: Little Devil paper model

In this part I will discuss how I use Pepakura Designer to create paper craft patterns from my low poly models. The starting point is to take a 3D model created in any 3D modeling software and use Pepakura Designer to create a 2D pattern that when cut, folded and glued creates a 3D paper model.

Here I'm using a 3D model of a squirrel. I've UV Unwrap it in Rizom UV and textured in Substance Painter.

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In this process, I've opened the Fbx format of the model in Rizom UV.

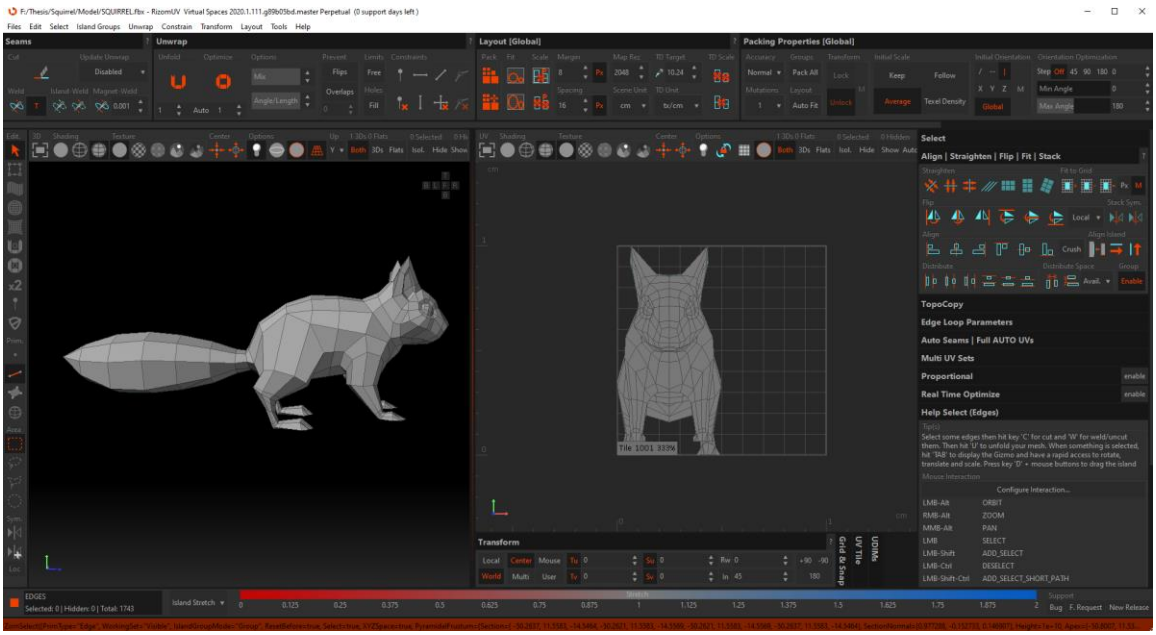

Figure 4.1: Importing the Squirrel model into Rizom UV

I then specified the cutline edges by clicking them and hit C on keyboard to cut.

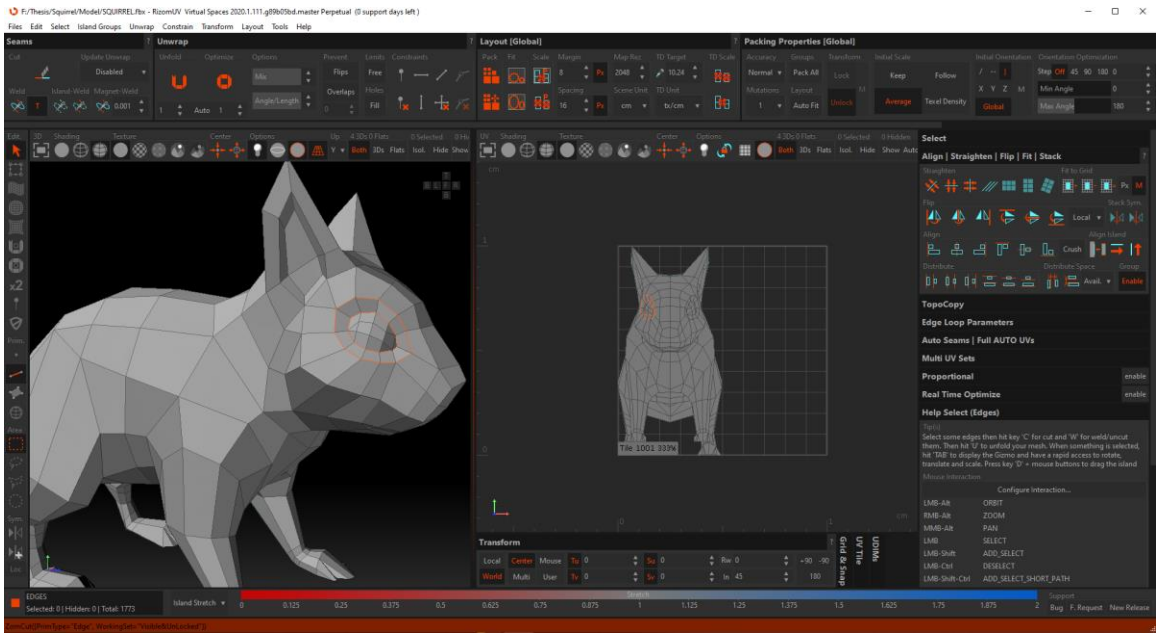

Figure 4.1: Specifying the Cut Line Edges

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I hitted U on the keyboard to unwrap the UV after cutting.

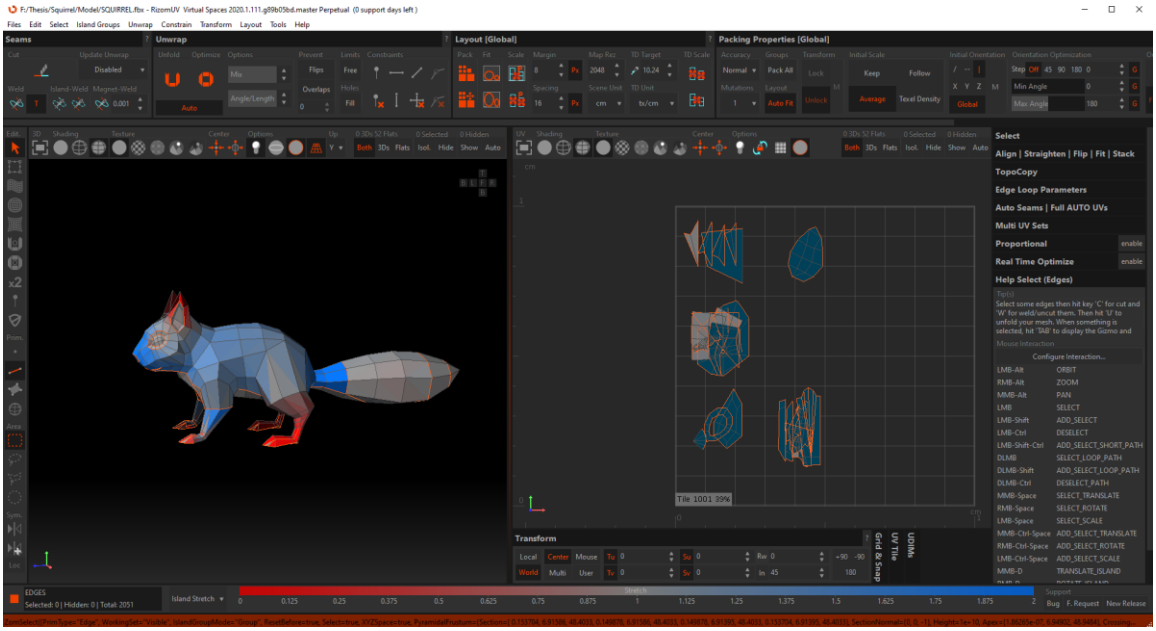

Figure 4.1: UV Unwrapping

The UVs are then packed so they no longer overlap by pressing P on the keyboard.

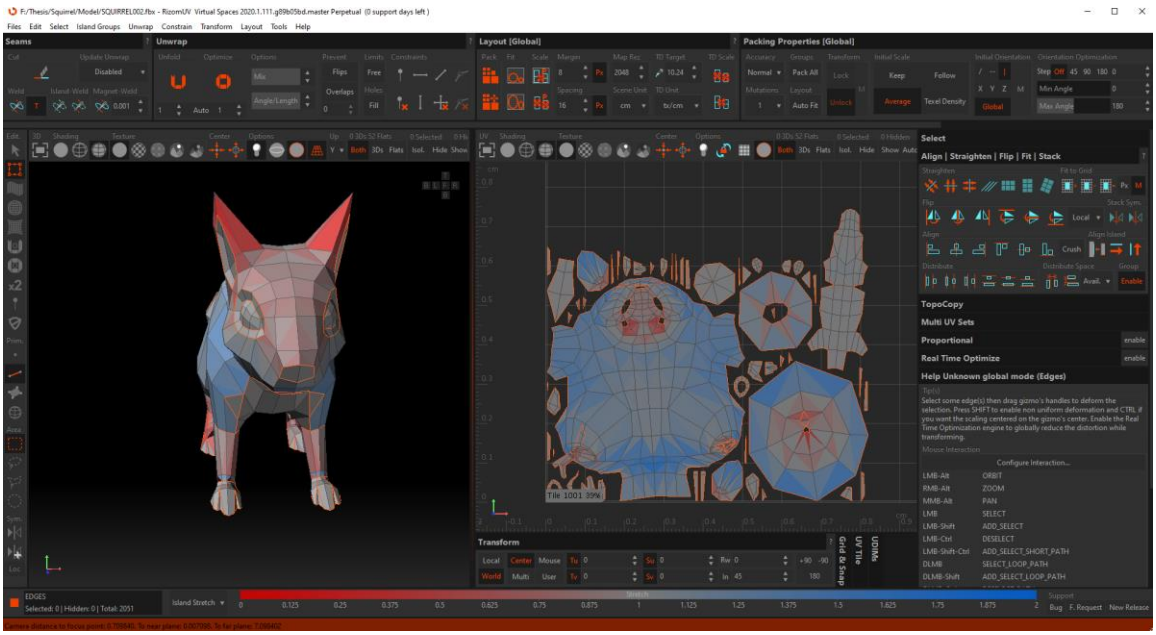

Figure 4.1: UV Packing

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Following that, I saved my file and opened it in Substance Painter to create a texture map.

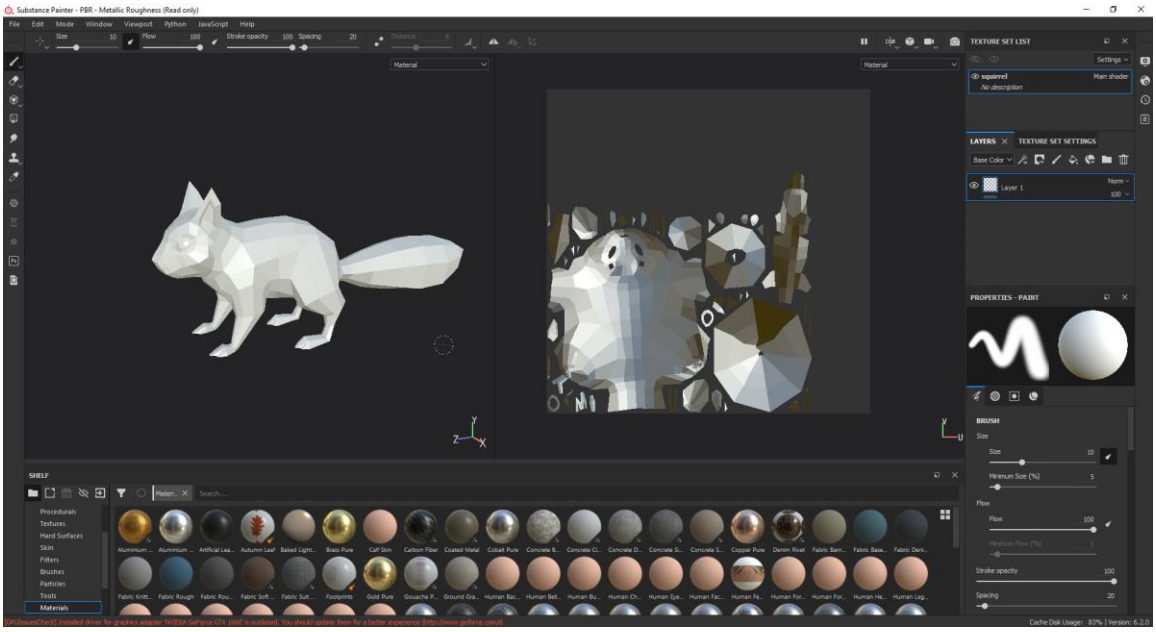

Figure 4.1: Importing the Fbx file into Substance Painter

Then added a fill layer to fill color as layer wise.

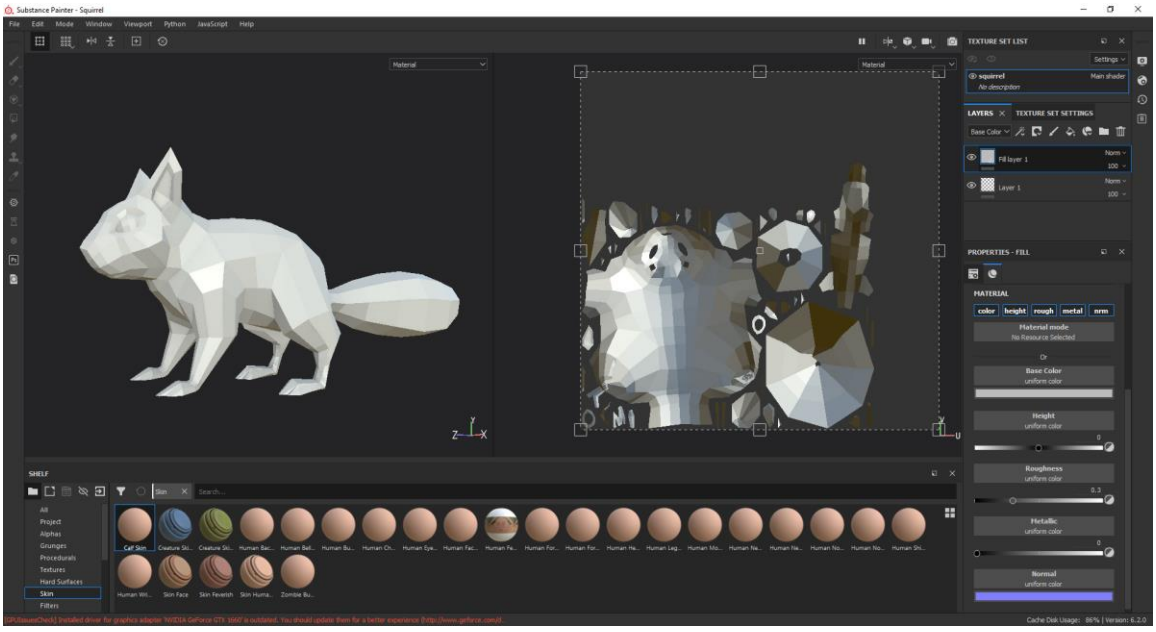

Figure 4.1: Adding fill layer

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Then added a black mask in fill layer.

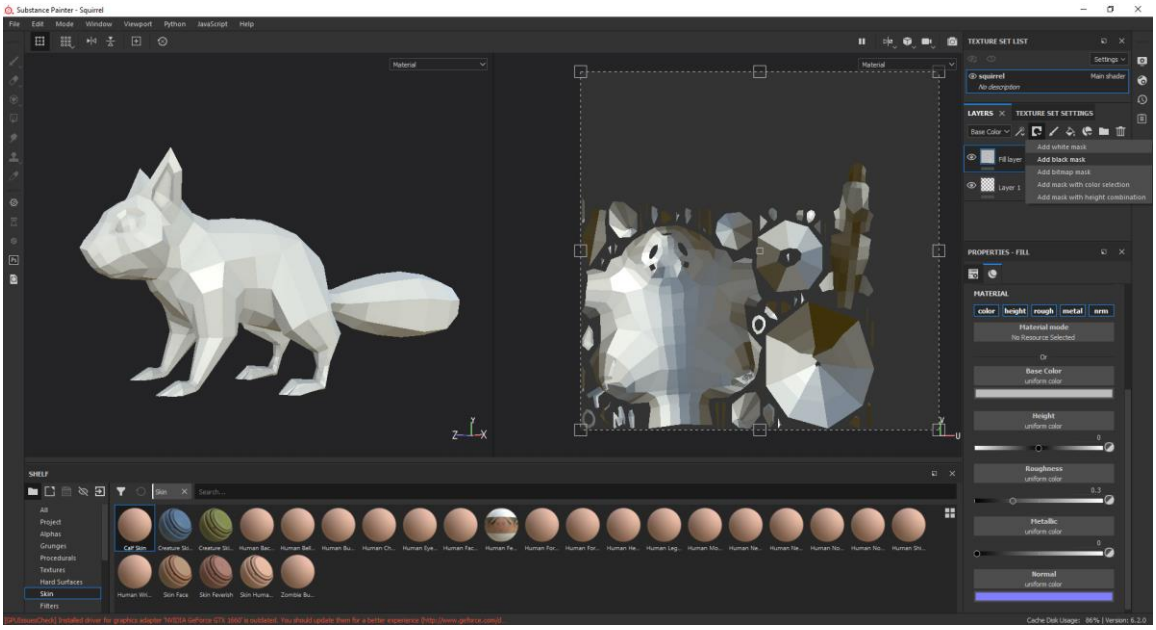

Figure 4.1: Adding black mask in fill layer

Also, changed the base color according to my requirement.

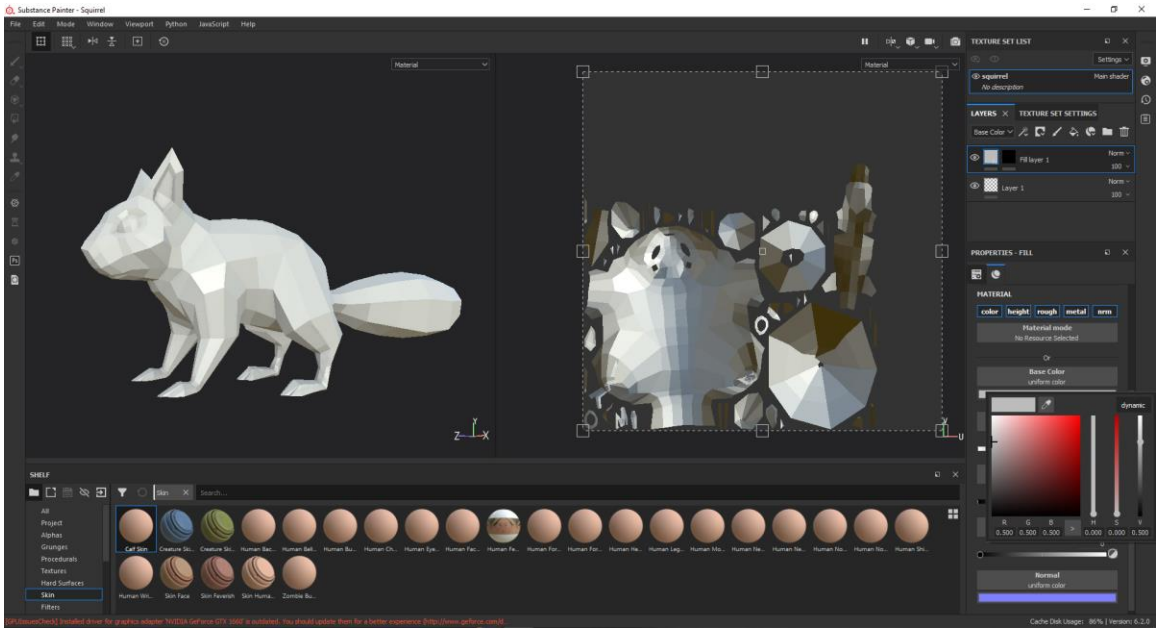

Figure 4.1: Changing base color

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I had filled my layers with the help of UV chunk selection.

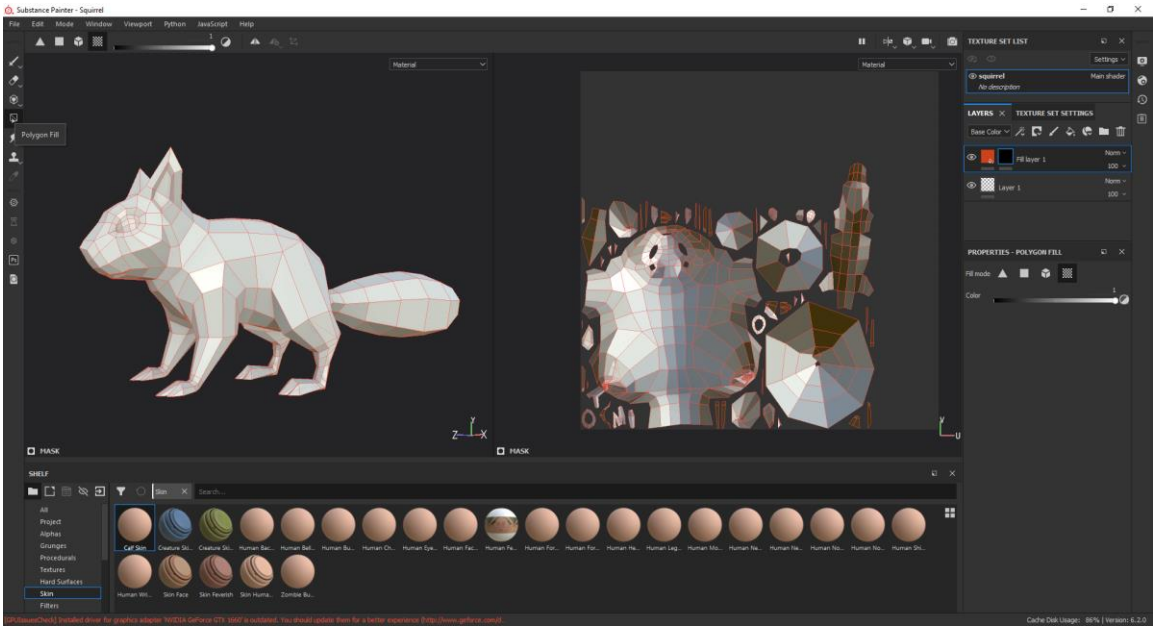

Figure 4.1: Polygon Fill Selection

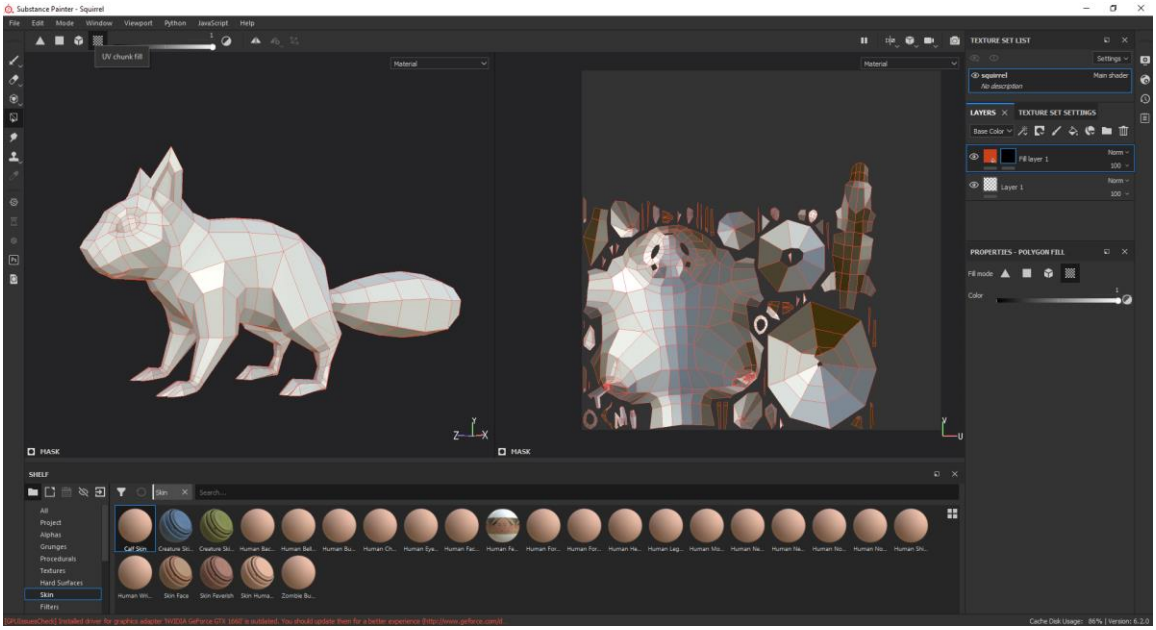

Figure 4.1: UV chunk fill Selection

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Then I started to fill different colors in different masking layers by selecting UV.

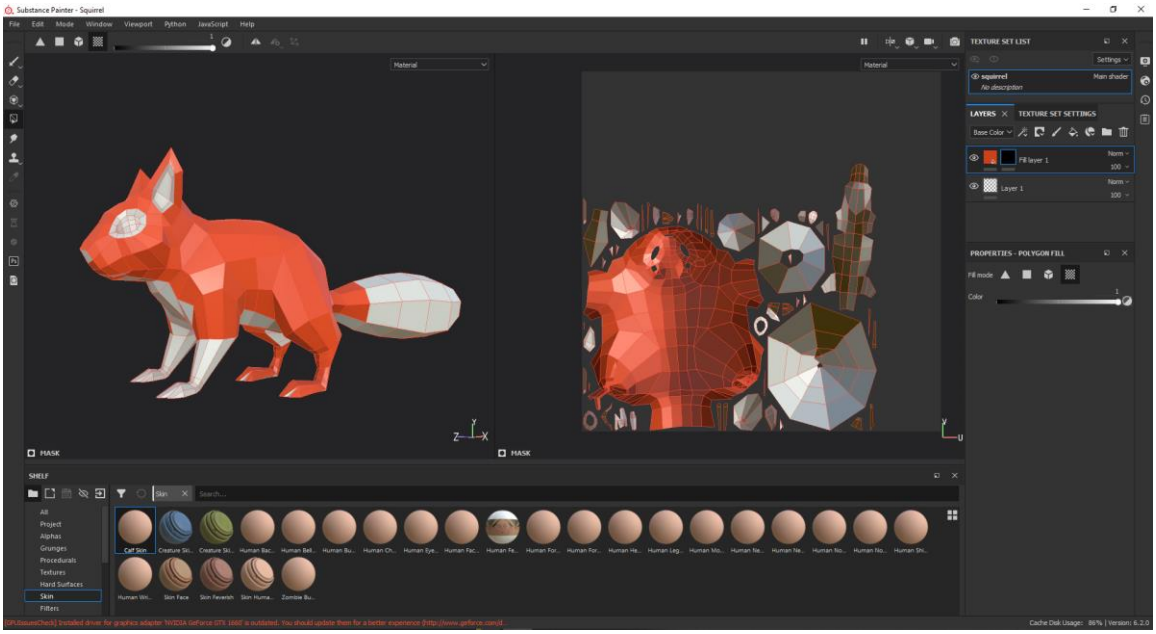

Figure 4.1: Filling masking layers with color

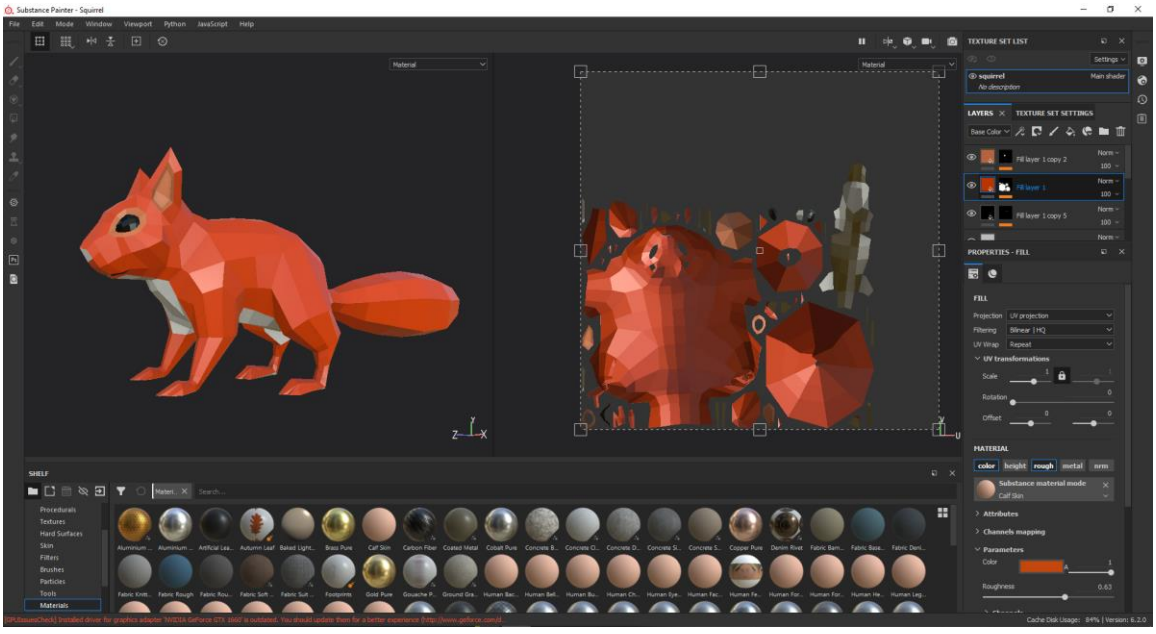

Figure 4.1: Layer wise different colors

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This was the output after filling all the colors.

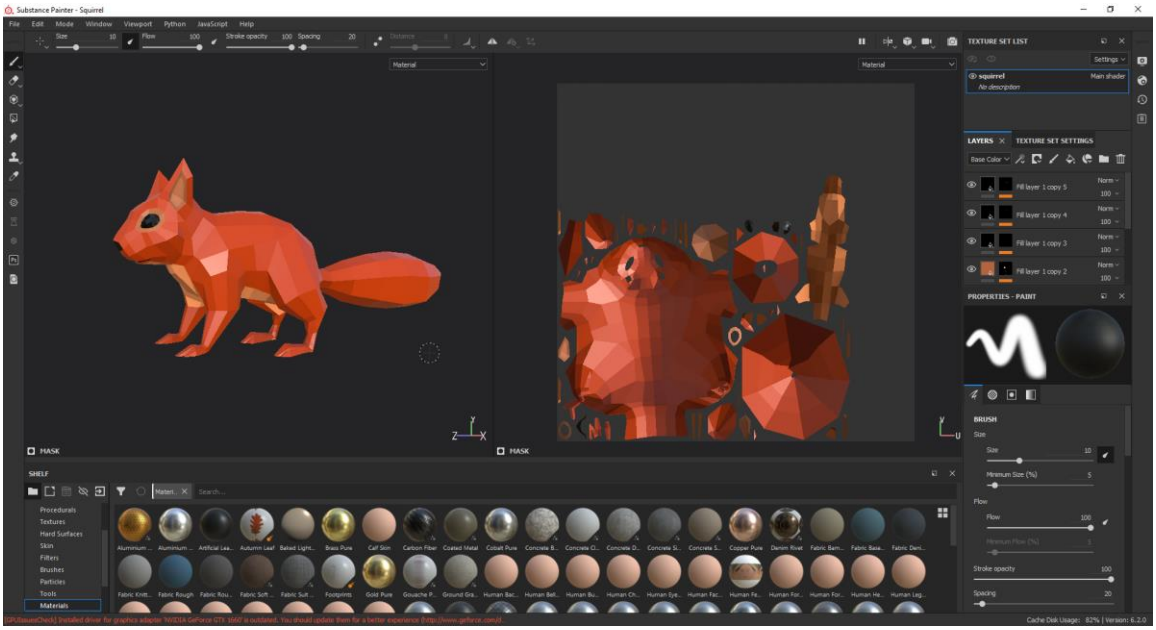

Figure 4.1: Squirrel with complete texture

After filling all the colors, I tried to set up the light and then I baked the combined 2D view texture of my squirrel to use outside of Substance Painter. Baking the combined textures made up of the lightening, normal, diffuse, and other maps. The steps are right below with snaps:

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File > Export Texture

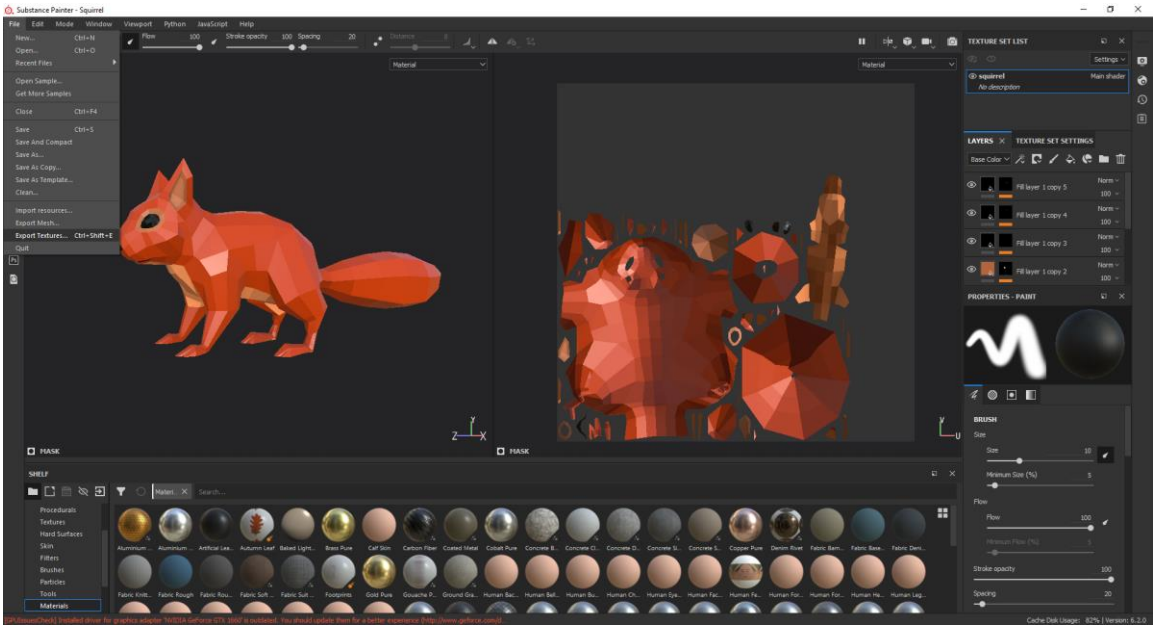

Figure 4.1: Baking 2D Texture 1st step

Output Templates > Plus button

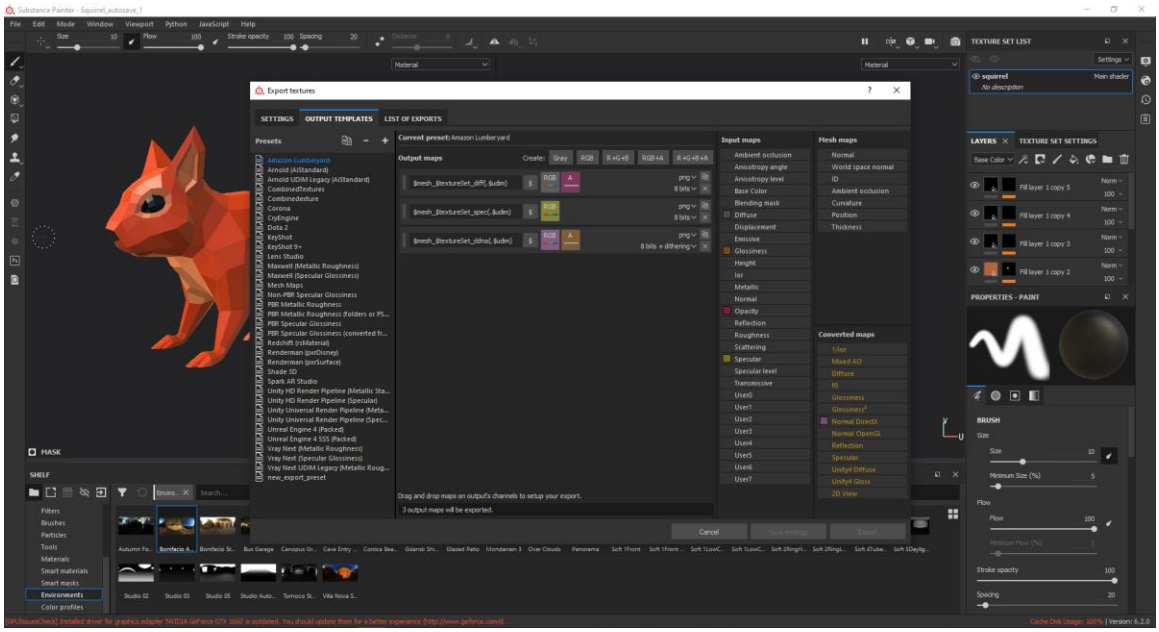

Figure 4.1: Baking 2D Texture 2nd step

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Name it any name

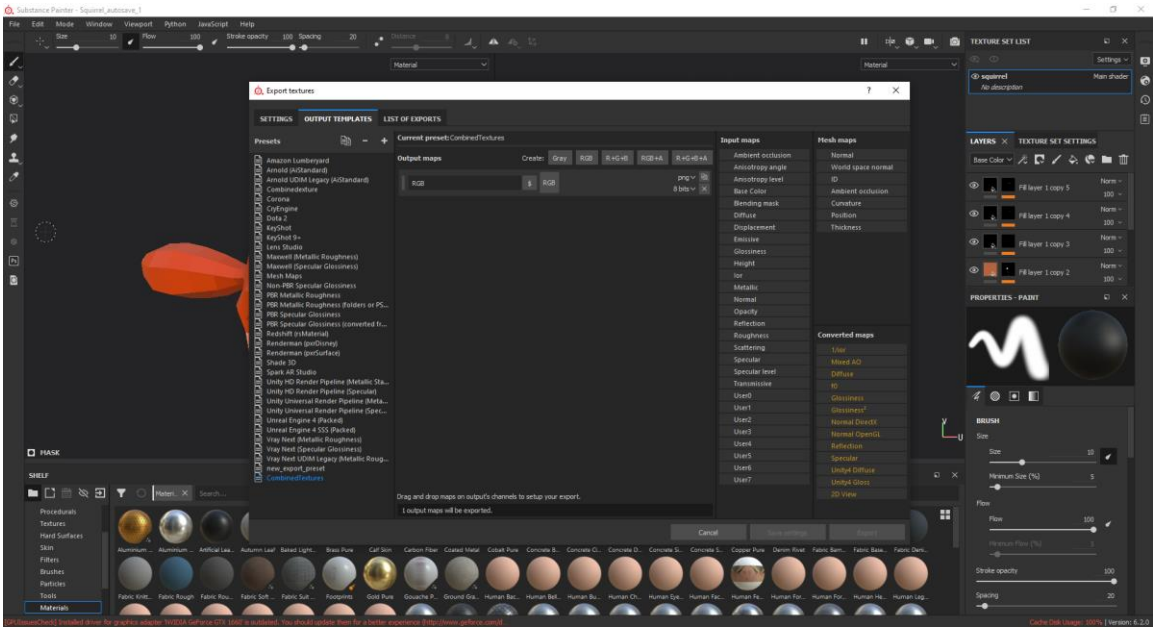

Figure 4.1: Baking 2D Texture 3rd step

Select RGB > From Converted > Drag 2D View > Place it on RGB > RGB Channel

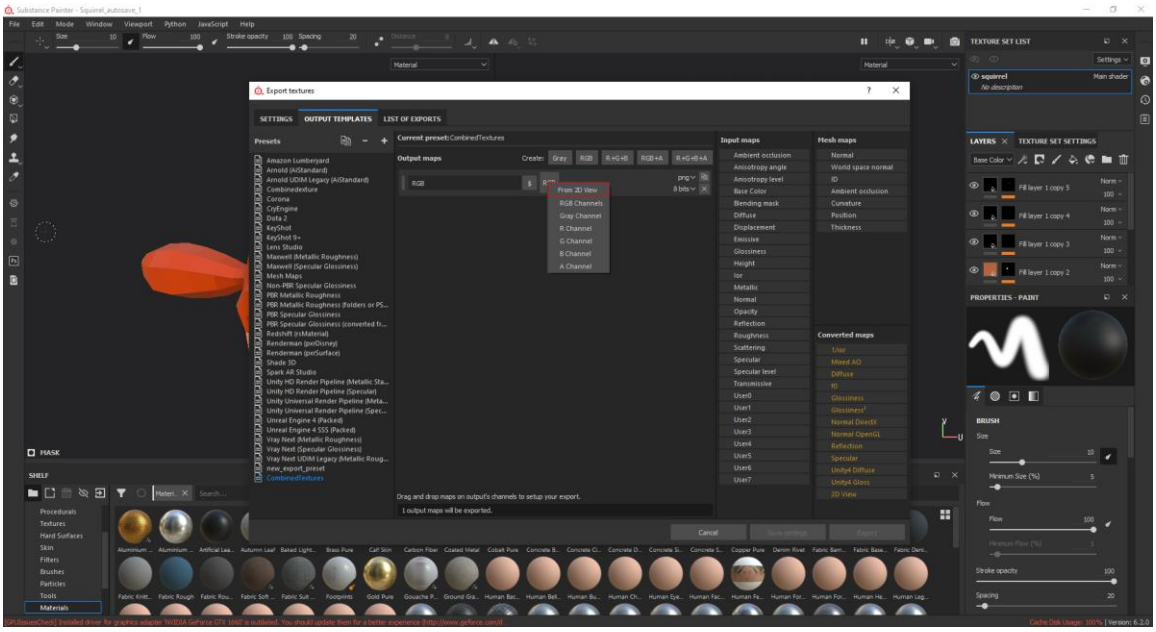

Figure 4.1: Baking 2D Texture 4th step

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Settings > Size > Highest Resolution

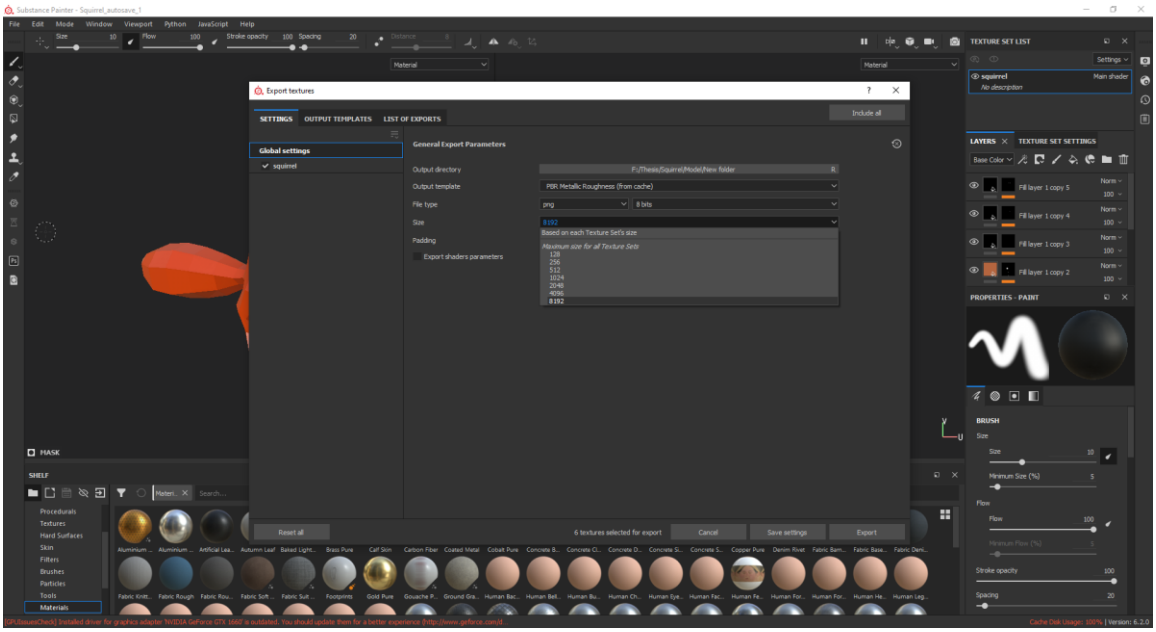

Figure 4.1: Baking 2D Texture 5th step

Output Template > Choose the one named >

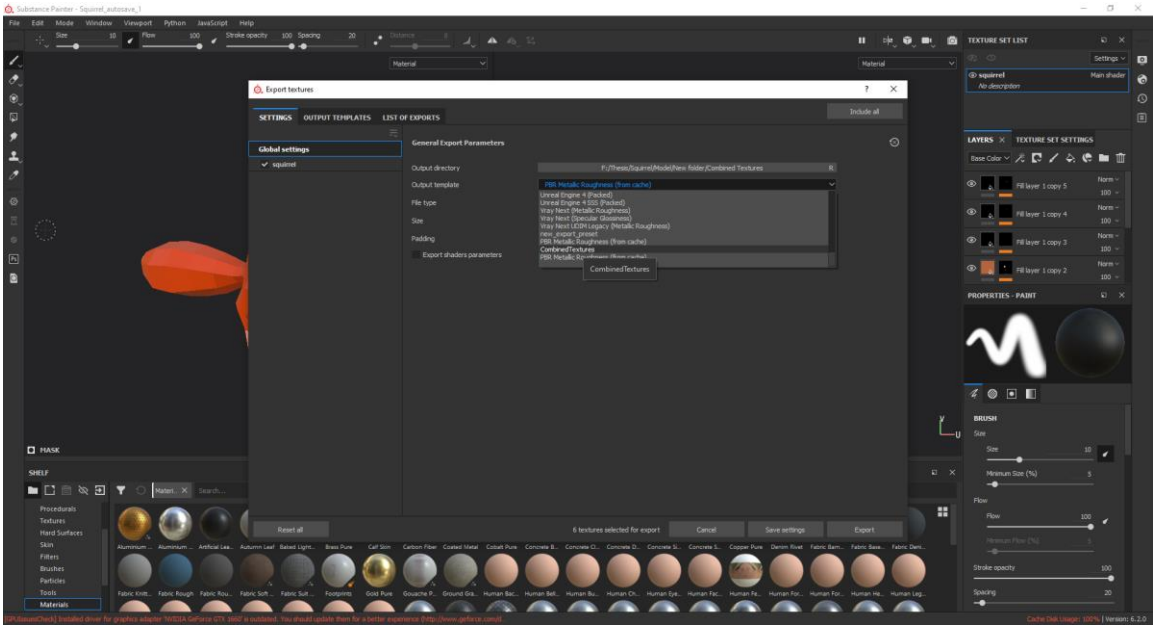

Figure 4.1: Baking 2D Texture 6th step

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Choose the output directory

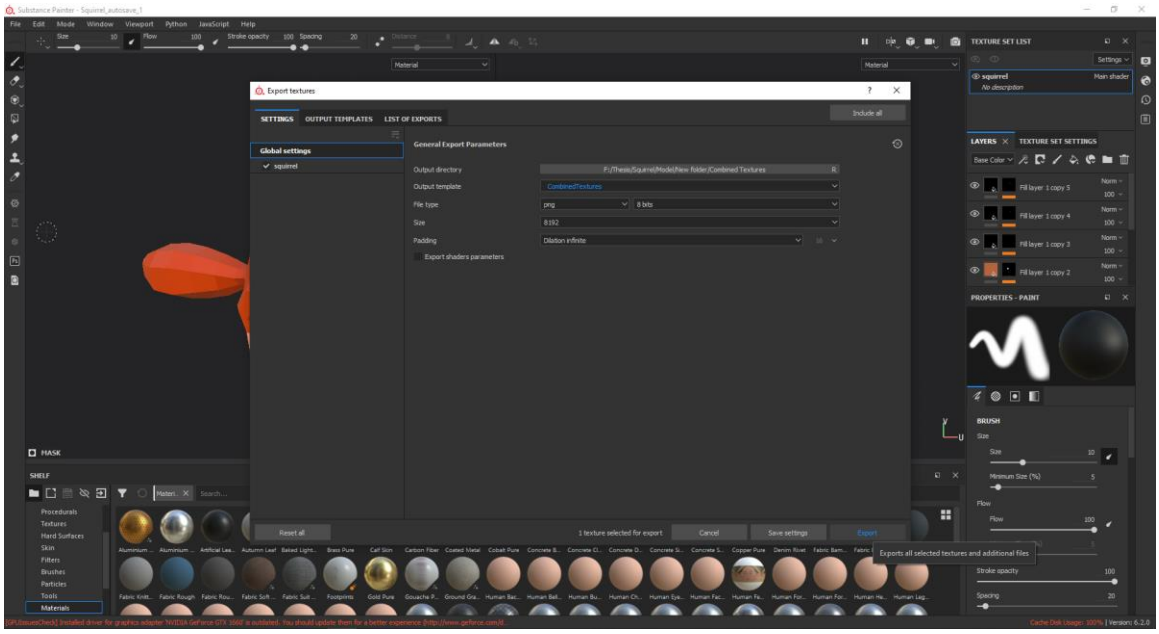

Figure 4.1: Baking 2D Texture 7th step

Export and wait to bake.

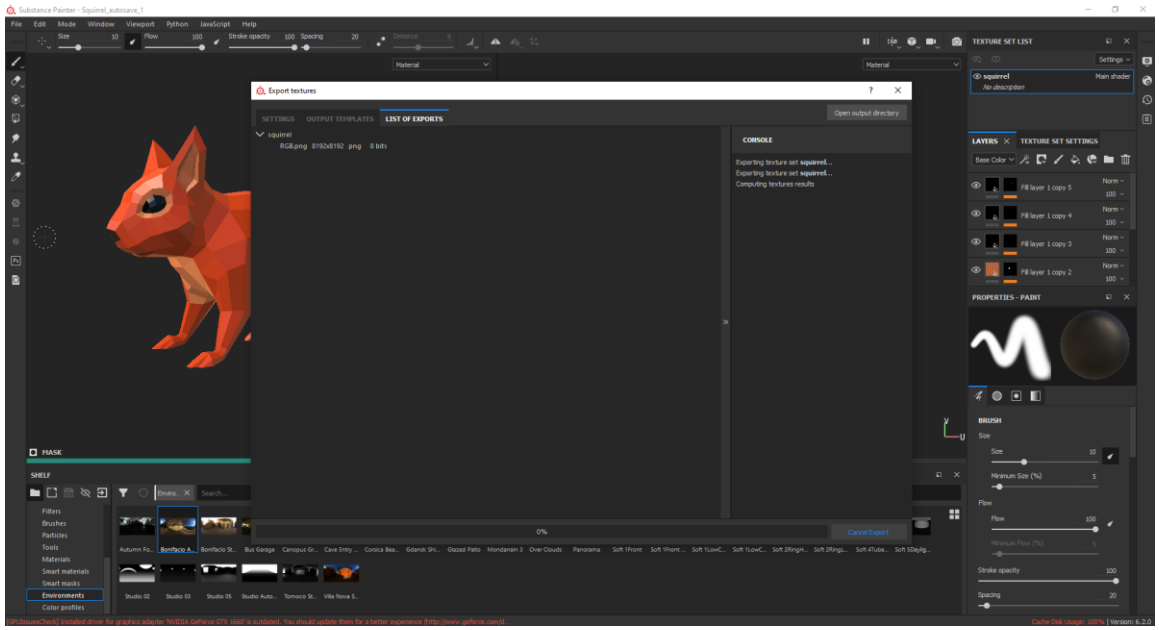

Figure 4.1: Baking 2D Texture 8th step

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Here is the baked combined 2D view texture of the squirrel.

Figure 4.1: Baked 2D Texture of the Squirrel

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After completing these steps, I exported the squirrel 3D model as a wavefront obj file which is going to starting point for using Pepakura.

With the program Pepakura Designer, we can unfold 3D mesh models to make paper craft creations. Unfolding required cutting the mesh into sections and flattening them. It is possible to automate this procedure or manually choose which edges should be trimmed first. The goal of automatic unfold is to create a pattern that requires extensive customization.

The Basic steps in Pepakura are:

- Open 3D model
- Seam the edges/Define the edge to cut
- Unfold the model
- Adjusting the scale
- Setting the page size
- Editing pattern
- Saving and printing the pattern

Here I'm describing my work process in Pepakura Designer right below:

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1. FLIPPING

The first step is to open the squirrel model which saved in obj. format. Pepakura supports a few different file formats but obj works just fine.

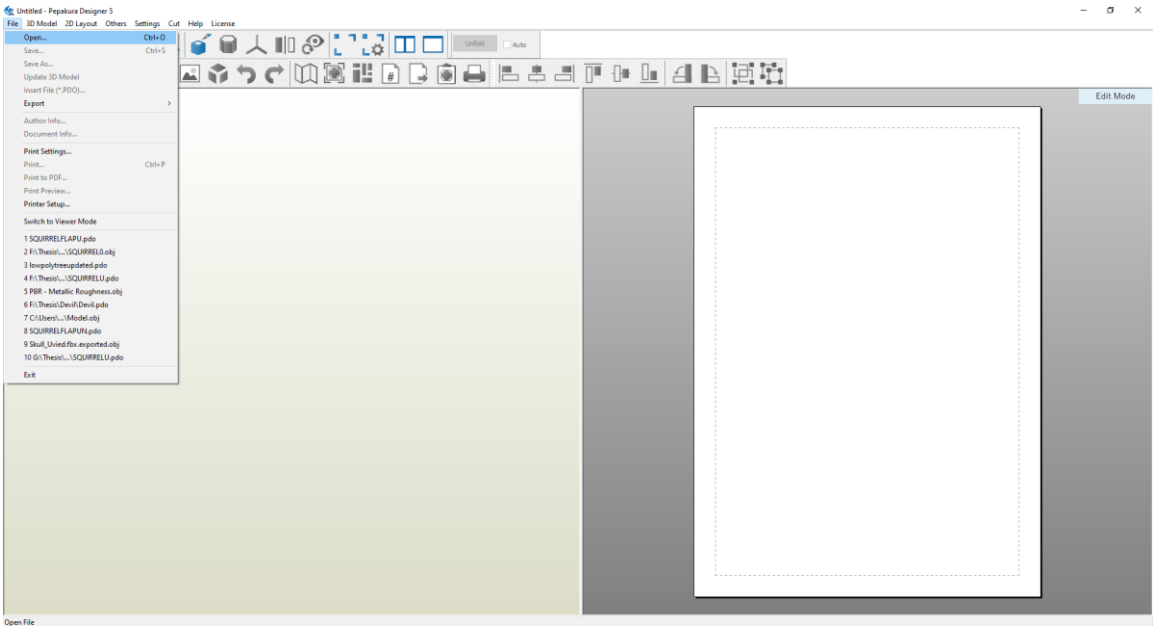

Figure 4.1: Opening 3D model in Pepakura Designer

When the model is loaded and just model coordinates appear the first thing is flip faces, which define the normal direction of the faces. Flip means turning the model inside out. The faces would appear dark gray if they needed flipping.

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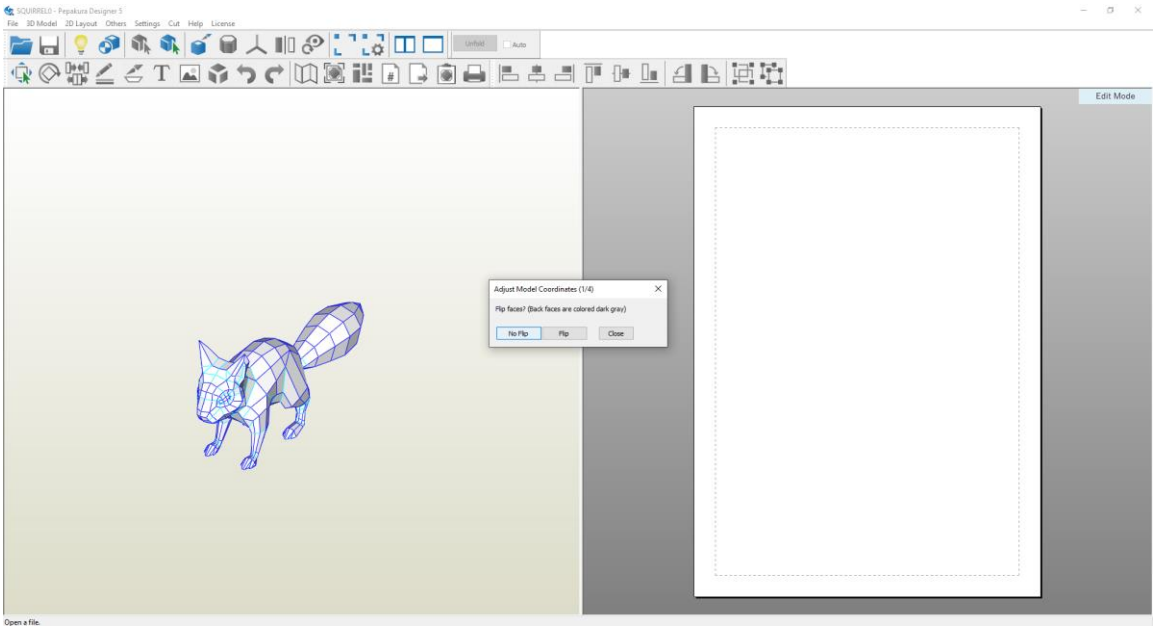

Figure 4.1: Flipping in Pepakura Designer

2. FRONT BASE

The next step to tell Pepakura where the front part of the model is. This is shown by red arrow here. The front of the model lines up, so it's okay.

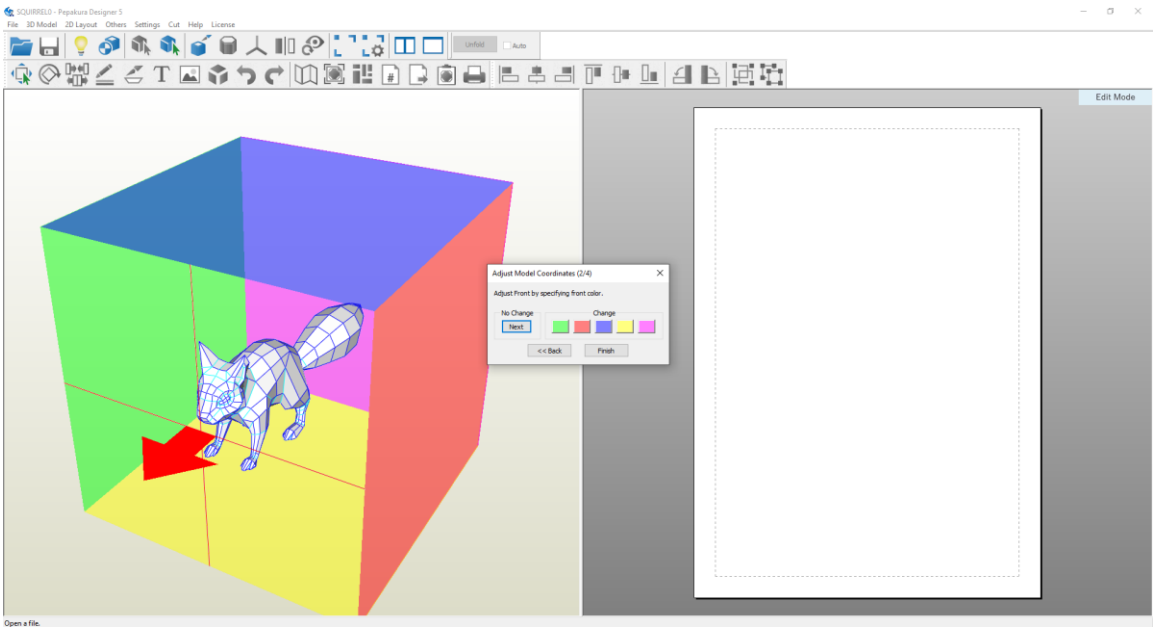

Figure 4.1: Define the front of the model in Pepakura Designer

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But if say the Squirrel's head was pointing to the yellow face then needed to click yellow in the dialog. Next thing is to tell Pepakura where the base of the model is, which is again shown by a red arrow. Here the Squirrel base and arrow all line up, so it's okay. If the Squirrel was rotated and the bottom was on the blue plane then needed to click blue in the dialog.

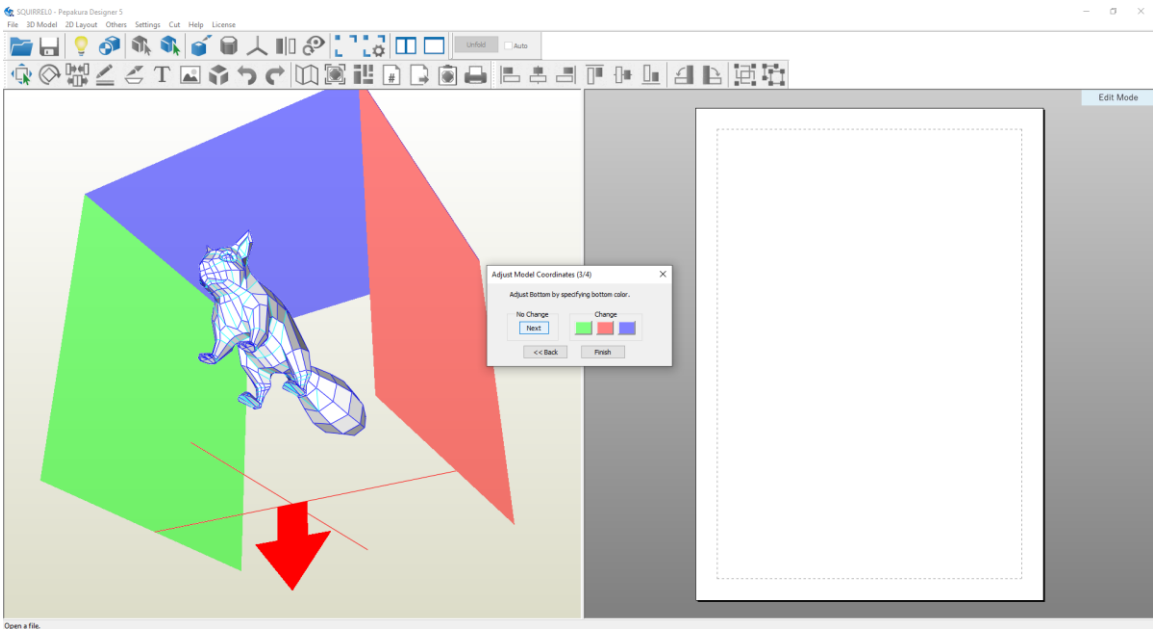

Figure 4.1: Define the base of the model in Pepakura Designer

3. INVERT STEP

In Pepakura Designer invert step which changes which side Pepakura interprets as left and which is right. This seems to affect the unfolding direction but since the Squirrel is symmetrical, it doesn't matter here.

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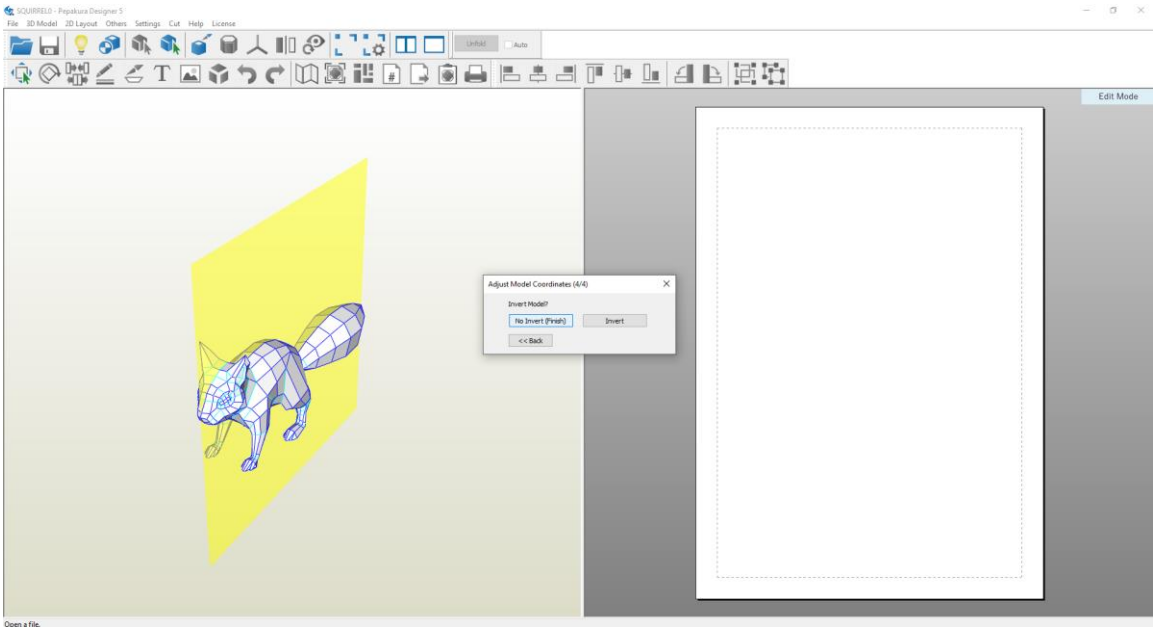

Figure 4.1: Invert step in Pepakura Designer

4. PAGE SIZE

Pepakura has two views. A 3D view on the left and a 2D page view on the right. The page is where the pattern appears when once unfolded it and at present it shows a single empty page. Then need to set the page size before unfolding. This is a size of paper that going to print the pattern onto.

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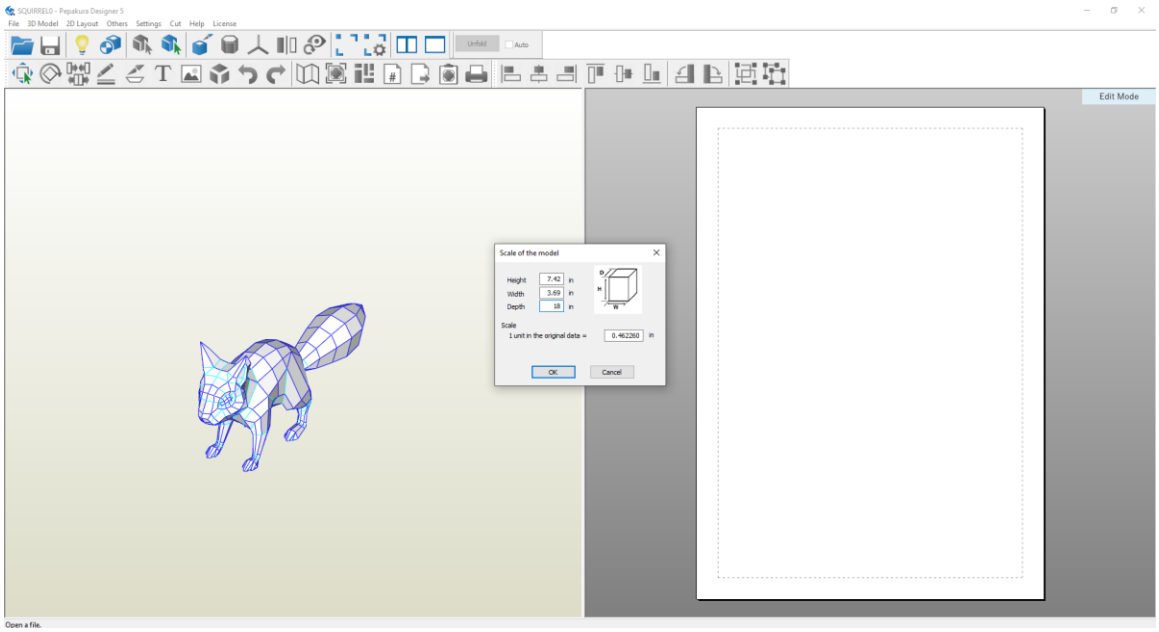

Figure 4.1: Setting scale in Pepakura Designer

The default is A4 portrait which is what I wanted and the rest of the settings are fine as well. Someone can just unfold the model at this point but the result will be a complicated pattern which will spend a long time cutting out and building. As we can see, the default on folding give shapes of different sizes which don't fit onto the pages. It's better to mark places on the 3D model which are meaningful features and which will make building easier.

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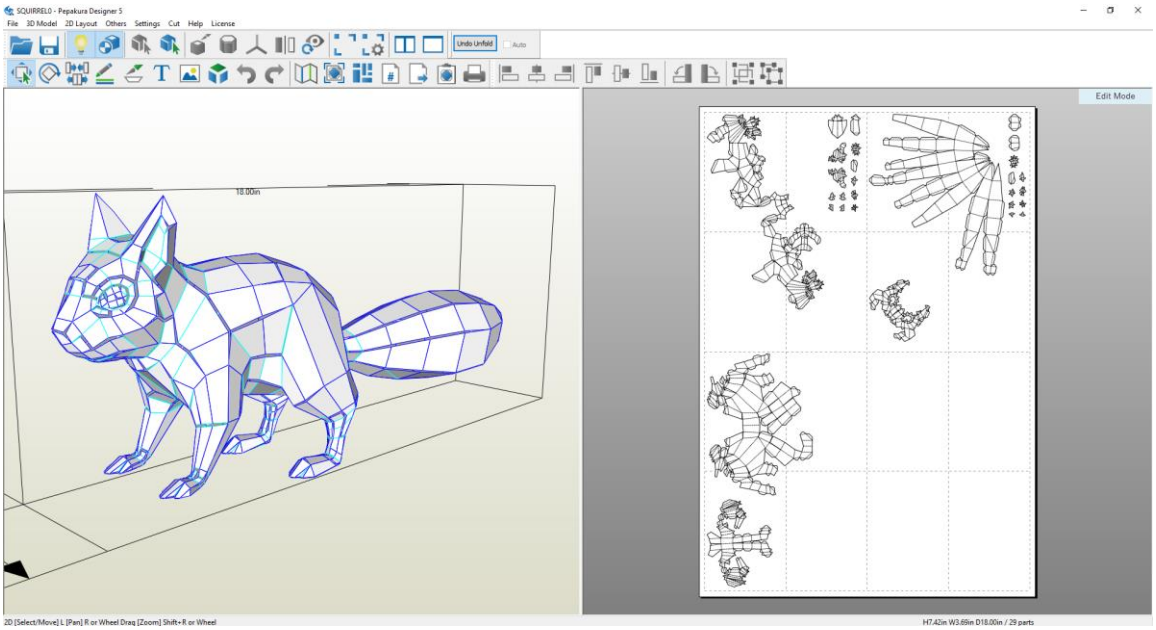

Figure 4.1: Output of Auto Unfold command

5. PAN ROTATE

As an aside, the status bar at the bottom shows how to move the view around. Mouse wheel down for pan. Right mouse clicks and drag to rotate and wheel rotate the zoom.

6. OPEN EDGE

In this case, I marked the main features on the model by going into 3D menu and selecting edit mode then open edge. This allow us to specify the edges to open. In edge operations hovering over the edge changes the color to green and left clicking marks it as an edge to be opened. Some edges are marked red and this shows that they are not connected to anything. Holes and extremities of the model are always red. If ever get mark and edge in error then it can be unmarked again by just left clicking again.

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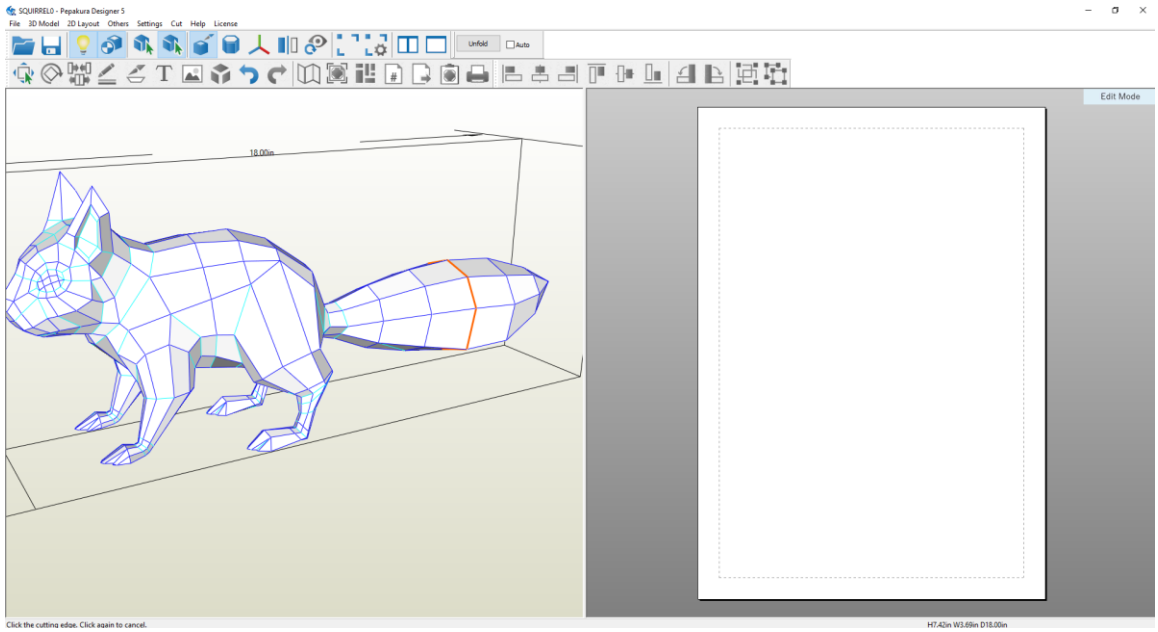

Figure 4.1: Define edges for Cutline

If model is symmetrical, someone can turn on pick symmetrical edge so that two corresponding edges are selected at the same time. This speeds things up considerably.

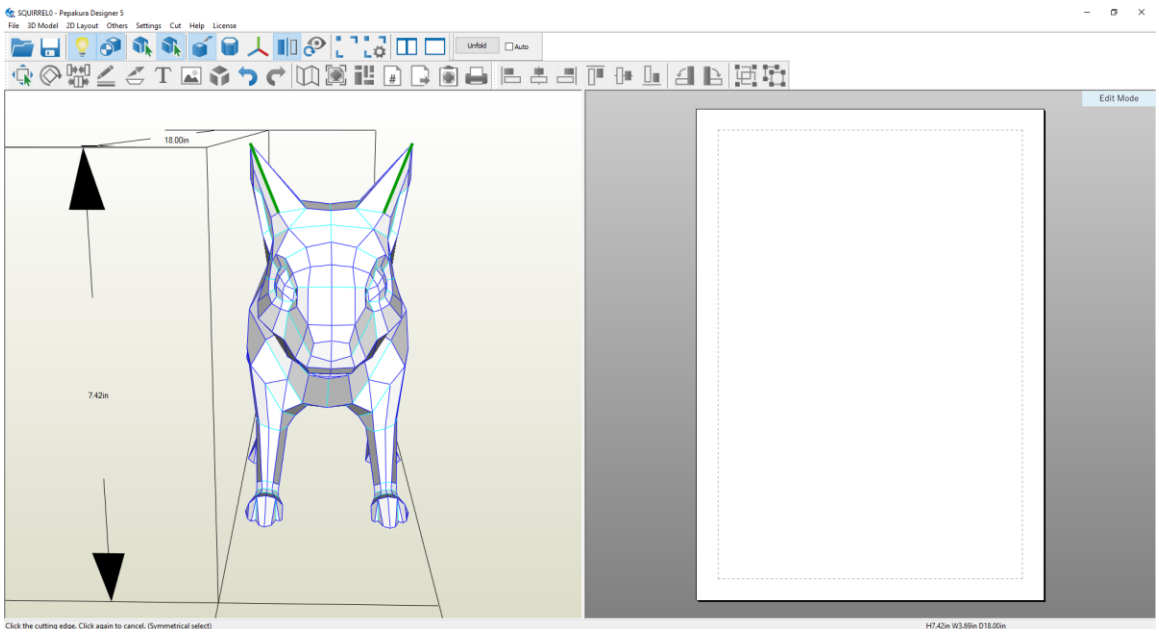

Figure 4.1: Symmetrical edge selection

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7. TEXTURE

At this stage I had imported my 2D texture map from settings.

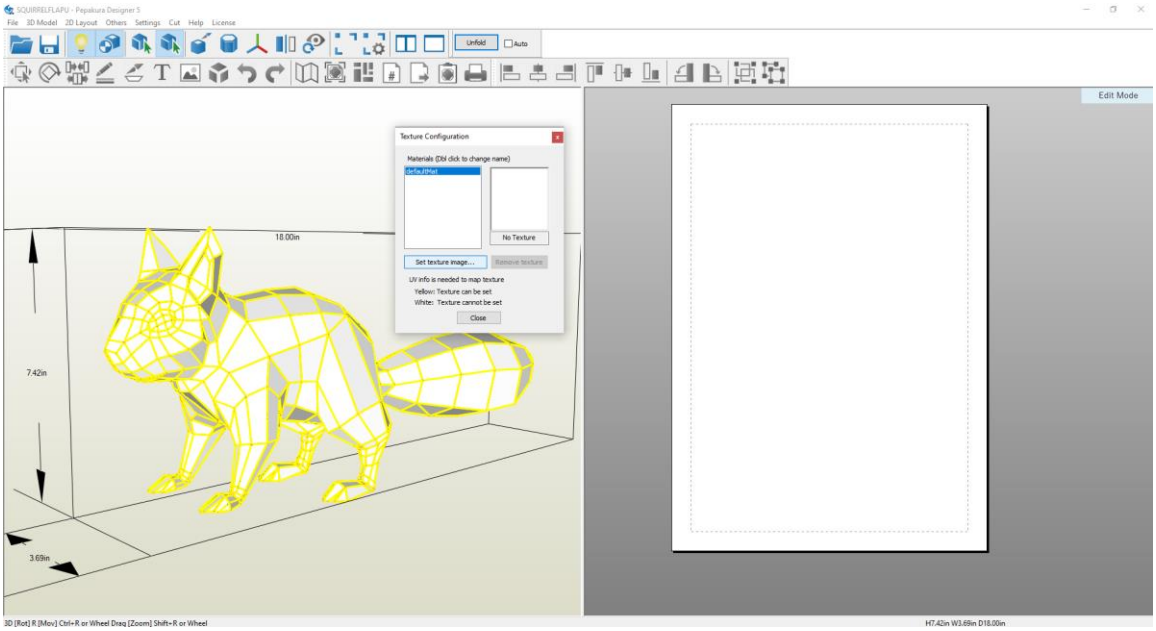

Figure 4.1: Opening texture config dialog

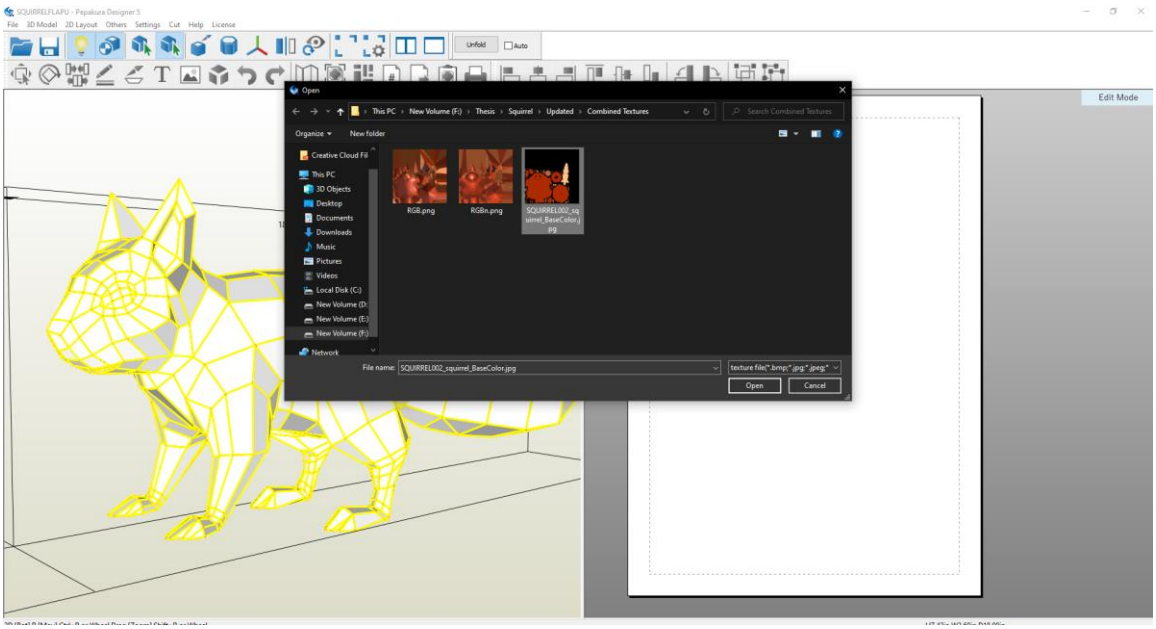

Figure 4.1: Selecting the texture map

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8. SAVE

Now at this time I saved my work. Pepakura projects are saved as pdo files which can be opened and printed using the free Pepakura viewer. There are a lot of decent pdo available on the internet.

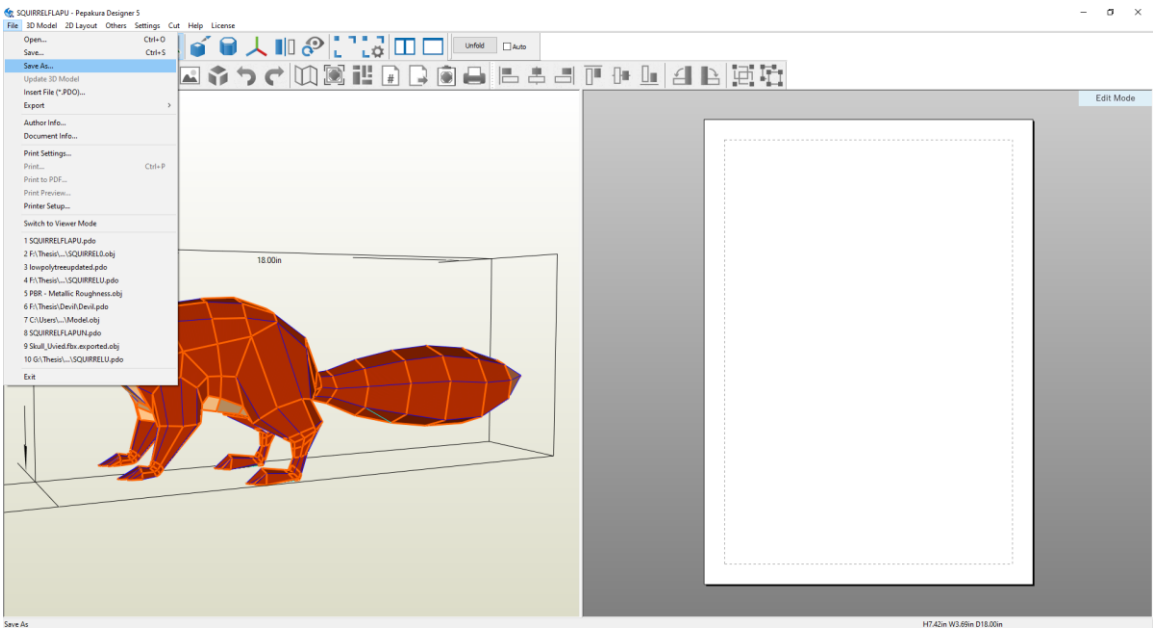

Figure 4.1: Saving pdo file

9. UNFOLD

At this stage I had unfolded my Squirrel. Unfolding generates the pattern on the page view. If auto selected, Pepakura scales the parts to fit onto a single page. Otherwise anyone can specify the size of the model the way they want before unfolding it. I determined the squirrel depth to be 18 inches. Pepakura unfolded the model using the opened edges as a guide. I resized the views and zoom in for a closer look. Sometimes some paths might too large for the page.

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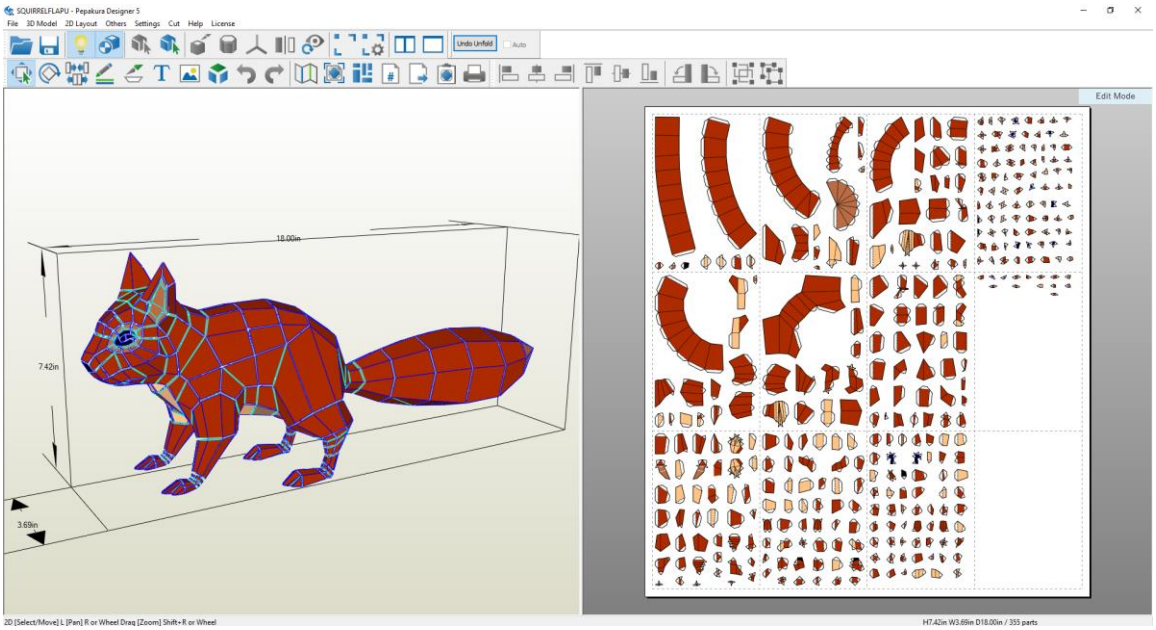

Figure 4.1: Generated unfolding pattern

10. FLAPS

Others like the eye region have a lot of split edges and overlapping flaps where gluing and cutting would be difficult. On the pattern the flaps are shown here. The dash lines are where it needed to fold. There are two different types of fold line. A valley fold which has alternative different size dashes and a mountain fold which here has the same size dashing. Solid lines are where needed to cut out. If someone left click on the part in either the 2D or 3D views the part gets highlighted in the other view. Also, if we double left click on a face the face gets highlighted as well.

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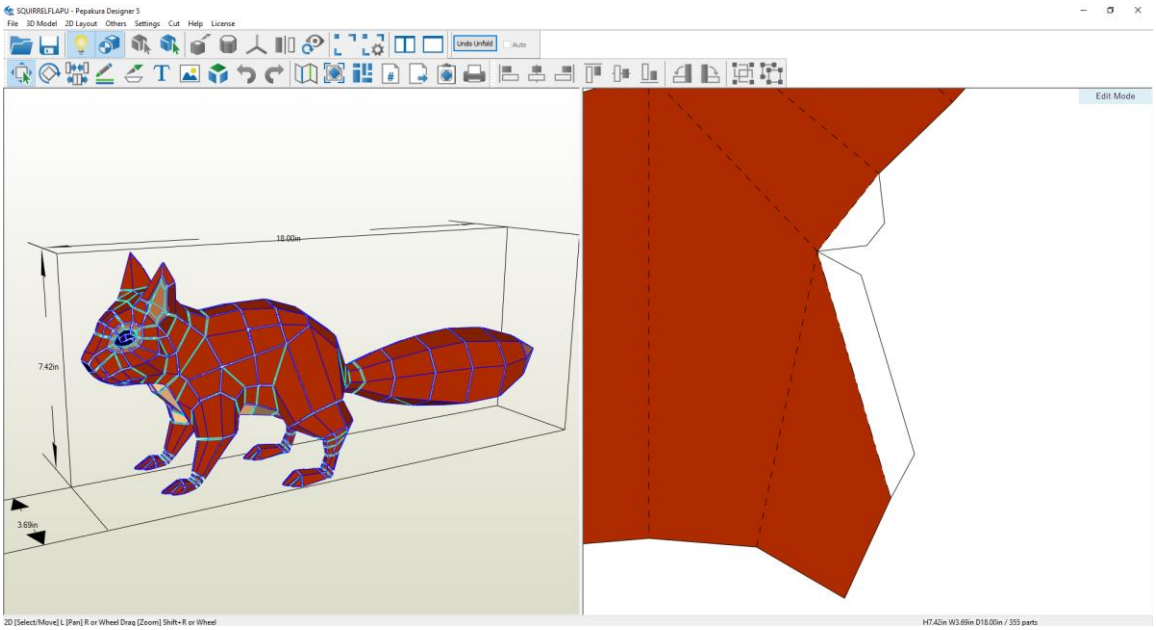

Figure 4.1: Valley & Mountain fold lines on Flap

11. SCALE

Before editing the parts I wanted to do a final check of the scale. I knew from measuring my 3D model that the depth part of the base opening is 18 inches. Which I've done so that it can be same as real size Squirrel. Pepakura provides a means to measure the distance between two points. So, I used it to check that my scaling was correct. The distance is 18 inches, so it's fine. If it was wrong, I can change the scale from the 2D menu.

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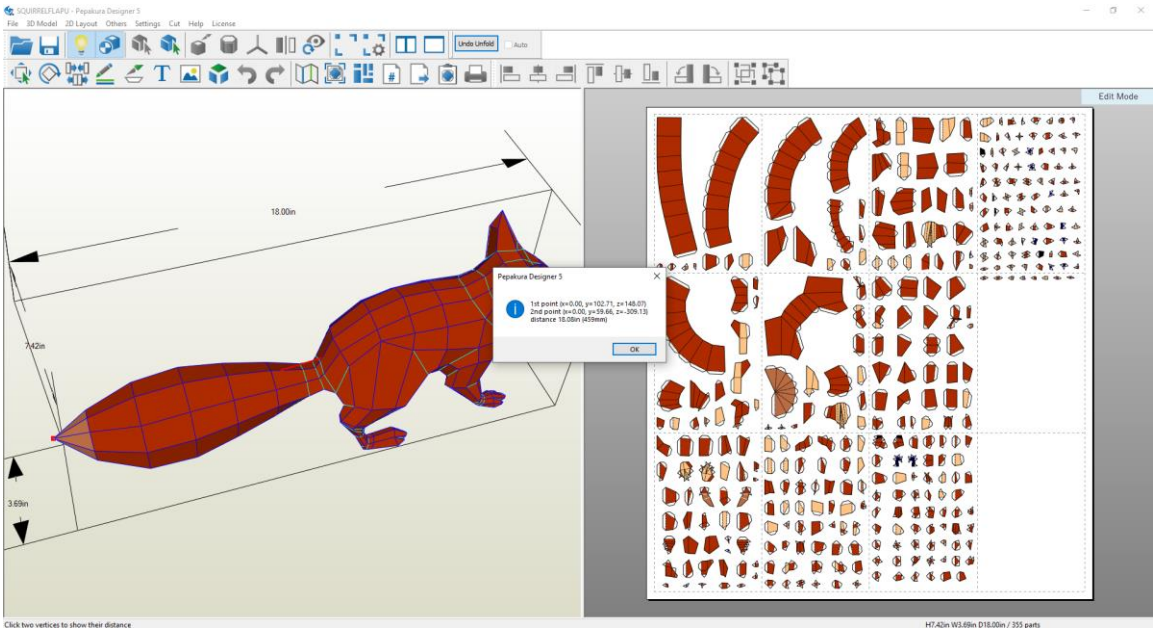

Figure 4.1: Scaling model to ensuring measurement

12. PARTS

In this part I arranged the parts a bit. I tried to keep connected parts close to each other as possible. Started by selecting the parts and roughly arranging them. In 2D view clicked to select and drag to move. Also, the green stick can be used at the top to rotate the part. I worked my way around the model, selecting parts and roughly grouping them together.

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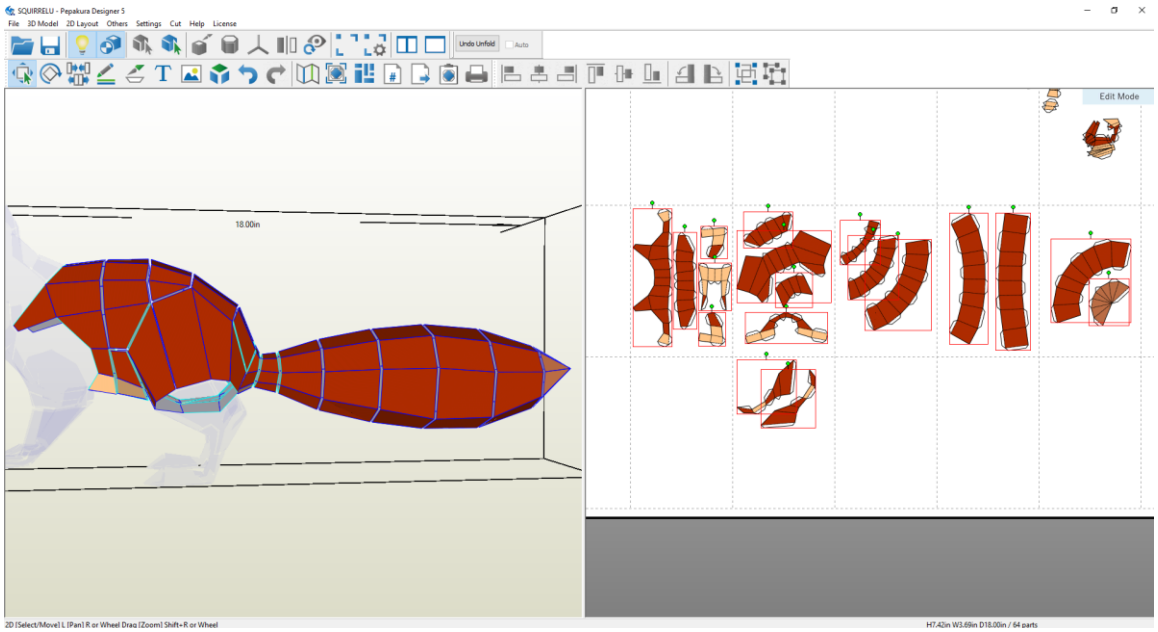

Figure 4.1: Keeping connected parts close to each other

13. FLAP SIZE

Before editing, it's important to decide on the size of the flaps we're going to use for the model. Smaller models need smaller flaps but this makes gluing a little more difficult. By clicking right in the 2D view and Edit Flaps can be selected. From the dialog box we need to select shape and set the height to what we want. Applying this to all the flaps, we'll notice that all of the flaps get a little larger.

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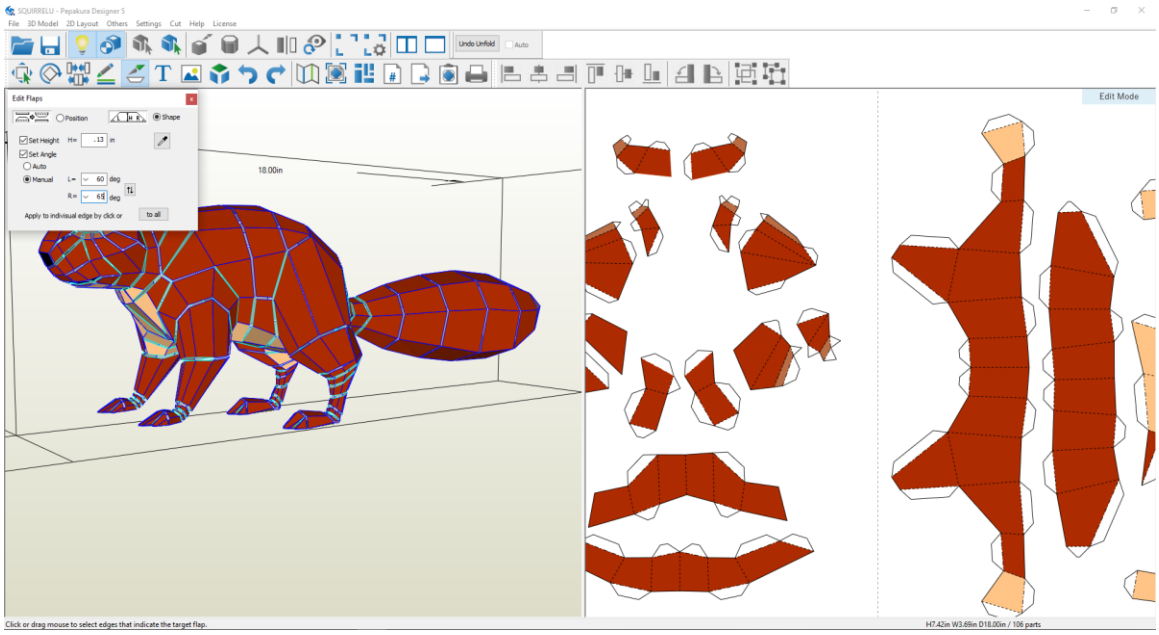

Figure 4.1: Editing Flap size

14. JOIN & DISJOIN FACE

We need to take each part and turn starting with the one we'll assemble first. In this case, I've chosen the eye region of the Squirrel. The problem with this part is that there are a lot of cuts and small flaps due to the angles between the faces. The aim is to turn edges into falls where I could and to make the parts as large as possible without losing the features too much and keeping it on one page. Then, I went into join disjoin face mode. Hovering over the 3D model shows the edges and folds being selected. Hovering over the part on the pattern does the same.

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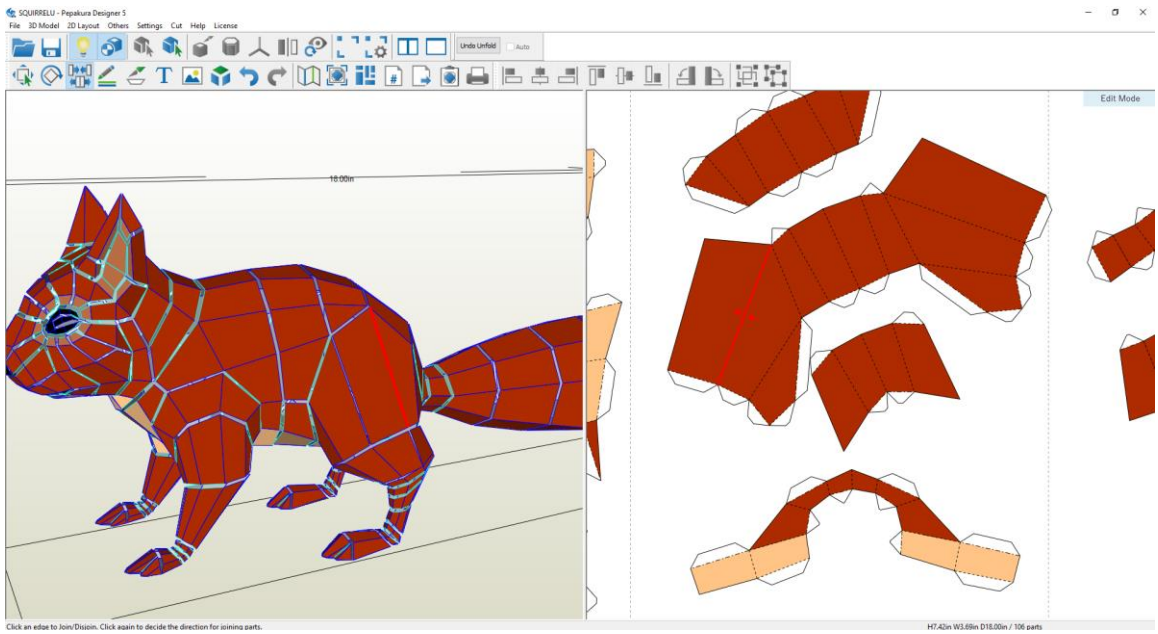

Figure 4.1: Join & Disjoin Face mode

Left clicking will either cut a fold or seal a cut as we can see. Depending on the face angles sealing a coat may cause a fold elsewhere to open. With the eye, I had chosen to separate the inner part from the outer part to make gluing easier. I moved them slightly to keep them together. Rotated using the green stick at the top of the selection.

15. CONNECTING EDGES

Hovering over a connected edge will allow us to see a green line which shows which of the edges is connected to. Left clicking forces them to join in the direction indicated by the arrow. I tended to work on the 3D view. I continued on like this resize and to create a large piece but with no overlapping flaps and no split faces until the model is complete. Since this model is symmetrical, I did one side first and then just repeat for the other side.

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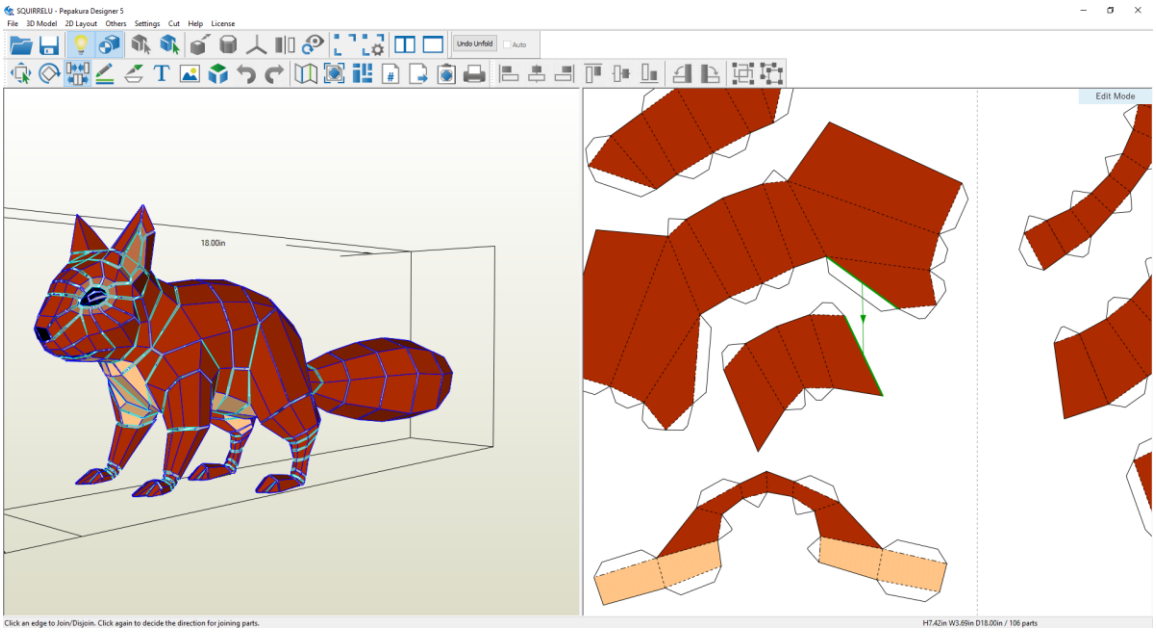

Figure 4.1: Green line indicates connected edge

16. ARRANGING PARTS

The next step is to arrange the parts to minimize the number of pages used. On symmetrical models it is helpful to keep the left and right side separate even if this takes more pages and also keeping connected parts together. This makes it easier to organize and assemble the parts after they've been cut out. Since I ended up with two pairs of parts which are in some sort of order. I started by fitting the largest parts first and then using the smaller parts to fill in the gaps. Then picked select and move mod to grab and rotate the parts into position. Tried to align long straight edges with the edge of the page leaving a small gap between. The dashed lines represent the page margin. We can also change this in the print and paper settings but the defaults worked fine for me. There are a couple of features which Pepakura provides to help with arranging parts. One is a grid and snap to grid feature which is set from the 2D menu. Snapping works using the bounding box of the part and the grid.

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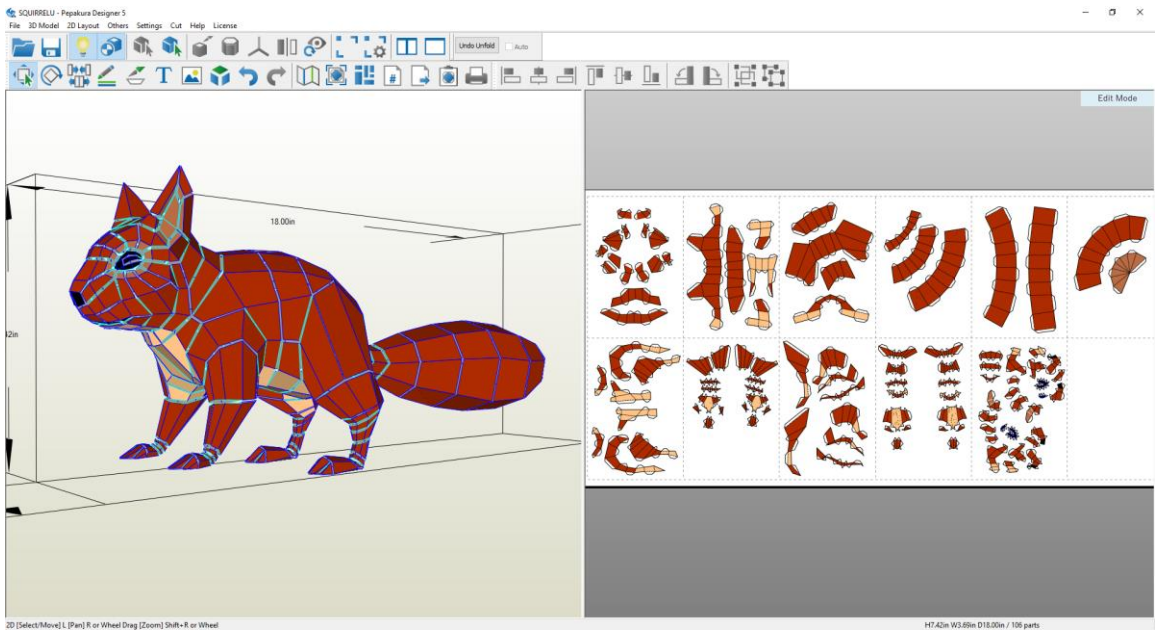

Figure 4.1: Arranging parts

17. ROTATE MODE

Another thing for aligning is to use rotate mode. If we double click on an edge and it has an angle of less than 45 degrees then it rotates to horizontal alignment and if greater than 45 degrees it rotates to vertical alignment.

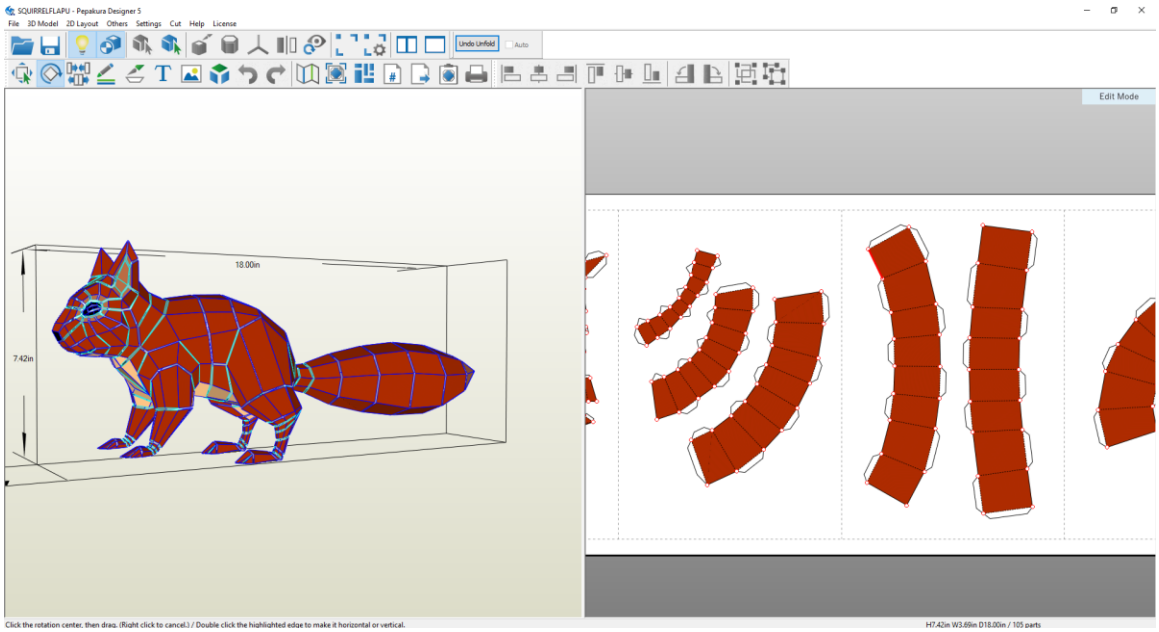

Figure 4.1: Rotate mode

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18. LAYOUT

I continued to arrange the parts until I became happy with the overall layout.

19. PATTERN

As we can see, the pattern has been separated into eleven pages. I tried to keep connected parts together wherever possible.

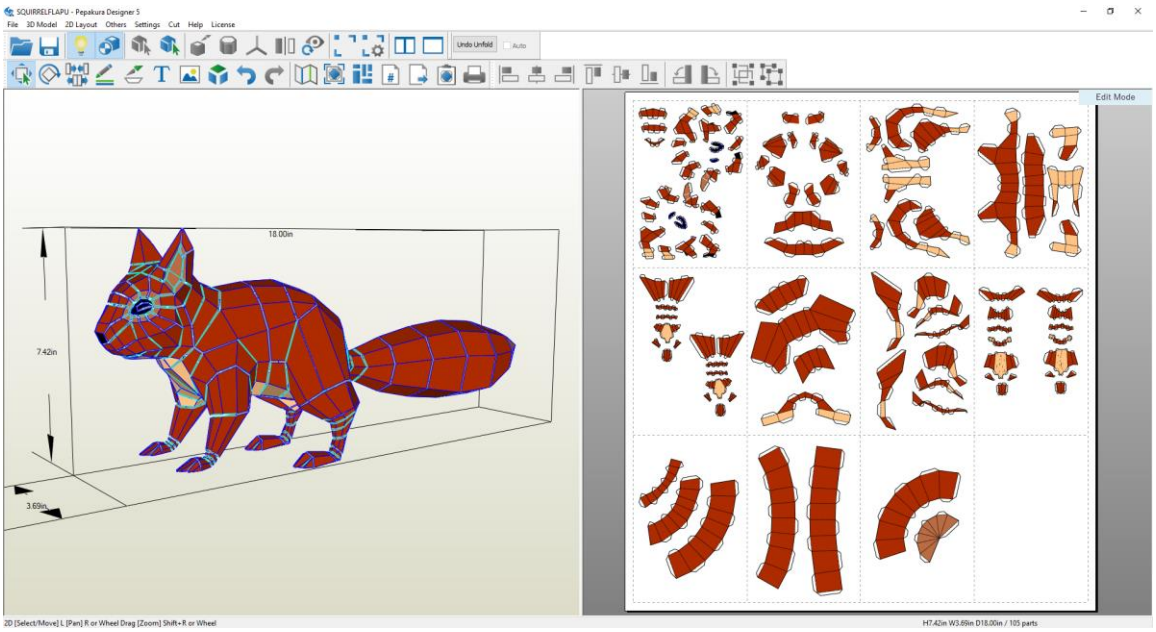

Figure 4.1: Final Pattern

20. MOVE FLAPS

The next step is to move some flaps around. I wanted to aim for a part having a flap on every other edge so that the two parts fit together better when being assembled. Parts where there are continuous flaps fitting onto another with a continuous edge are more difficult to align accurately when you're building the model. Some of the flaps on the outside should be moved. Then I went for Edit Flaps and select Position. I hovered over the edge to see where it connects and which made sense to me, I kept clicking to move the flap.

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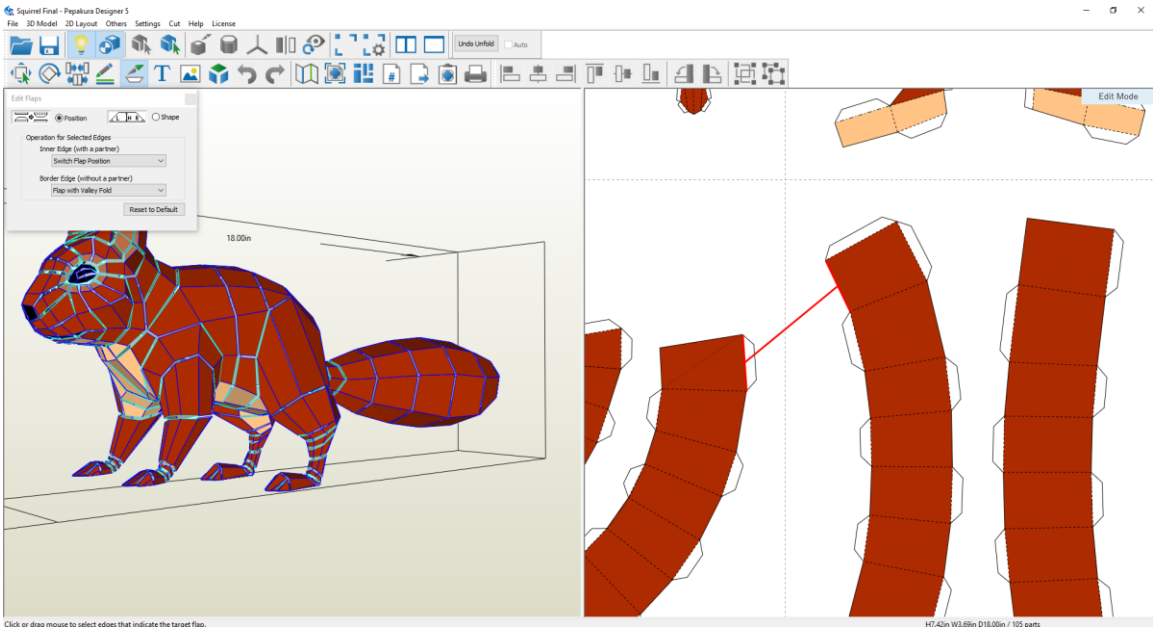

Figure 4.1: Moving flaps

21. EDIT FLAPS

Sometimes moving a flap causes the part to overlap another one. So, I had to rearrange them a little as well. I continued to edit the flaps until I were happy with the flaps spacing. There might be some parts where the flaps are not perfect since there will be an odd number of edges in places.

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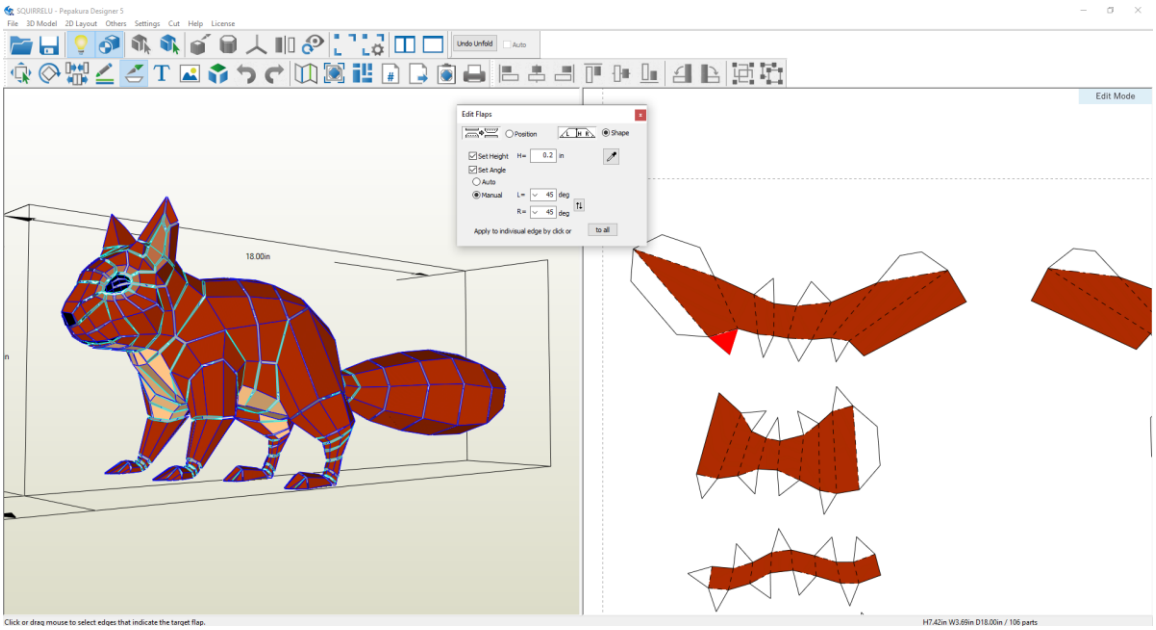

Figure 4.1: Editing Flaps

22. SET FONT SIZE

The final stage is to switch on the edge numbers and to set the font size. I would switch off the texture if I go for a plain pattern. But for my model I wanted to print out with texture. In case we go for plain pattern we need to go to the 2D menu and select Show Edge ID to show the edge numbers. As we can see, the same number appears on the edge and its correspondent opposite edge with the flap. Edges with the same number are fixed together when the model has been assembled.

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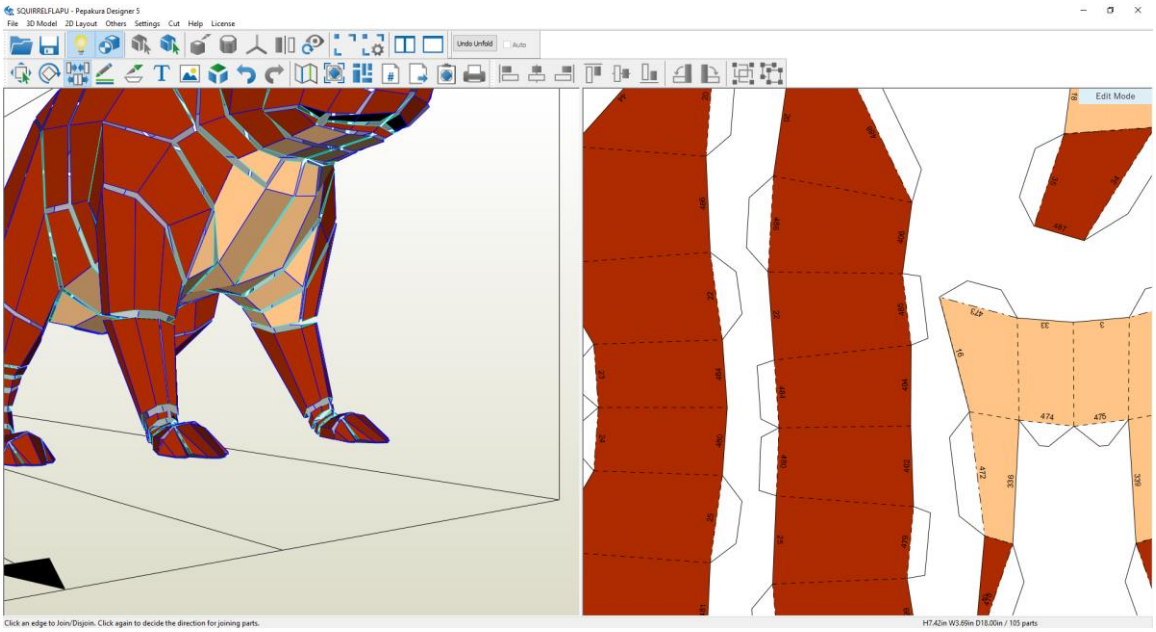

Figure 4.1: Setting Edge ID

23. PRINT TO PDF

Now, the final thing was to save my work and print the pattern. I prefer to print to a pdf first and then open the pdf in Acrobat Reader to examine the pattern for any problems.

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24. PRINT THE PATTERNS

The things I looked for the parts which overlap pages and making sure that there is adequate spacing between the parts. The final step is to printing the pattern and building it. At this stage, we're done to transform our 3D model to a 2D pattern.

Figure 4.1: Printable Patterns

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4.2 RESULT & ANALYSIS

I printed my layout on magazine paper once I had finished it. To achieve realistic color and gloss, I preferred laser printing. Then I started cutting the pieces from the pattern, folding and assembling all the pieces together. I began gluing the parts which has little pieces.

Figure 4.2: Assembled head & leg parts

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I eventually started to join the larger parts in this manner.

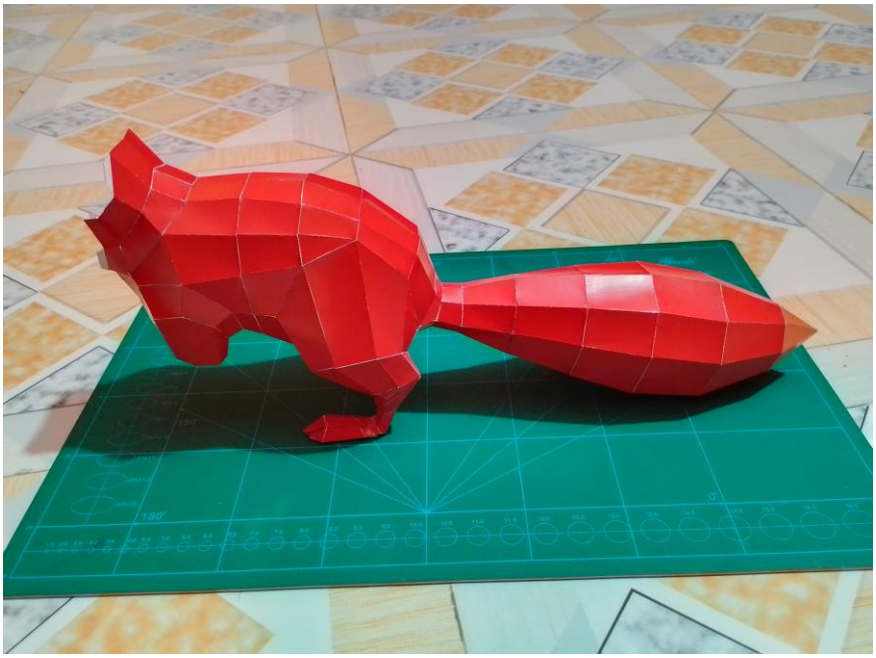

Figure 4.2: Joined larger parts

And in this way, I've finished my entire model.

Figure 4.2: Complete Squirrel Paper model

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Figure 4.2: Two complete Squirrel Paper model

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I tried using a model with high poly-count, but the outcomes weren't great. After unfolding in Pepakura Designer the outcome was something like this:

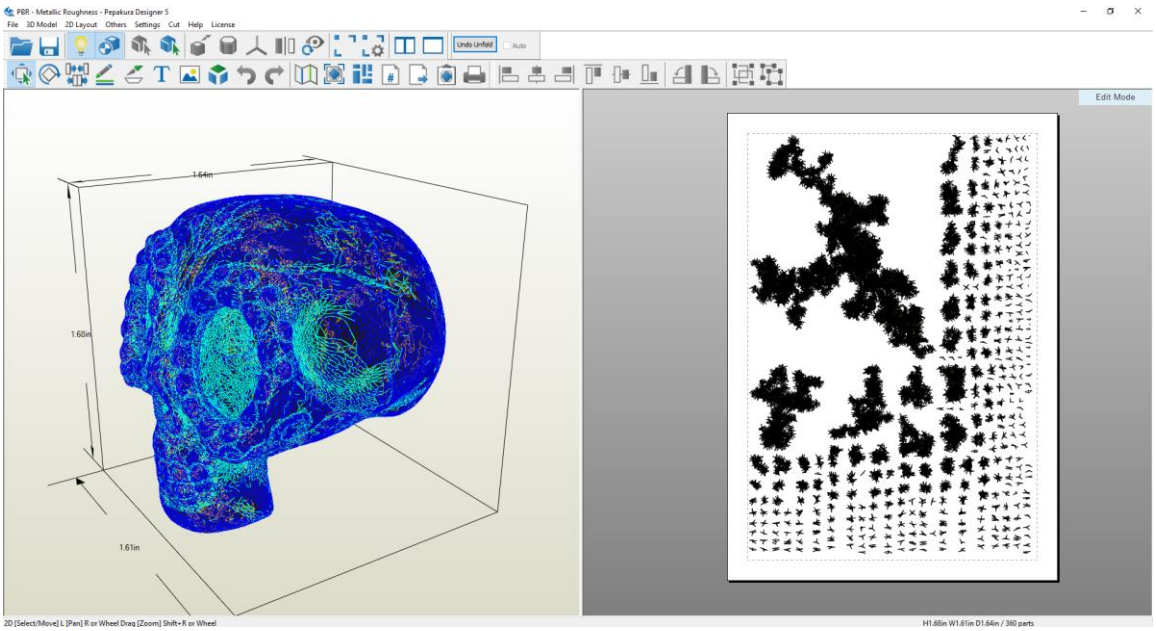

Figure 4.2: High poly-count model in Pepakura designer

Pepakura Designer has requirements for creating paper model layouts from a 3D model. That model has to be with a cleaner topology and low poly counts as much as possible. Otherwise, that model requires retopology.

An interesting feature about Pepakura is it allows data to be saved in DXF format. This format is a useful tool which allows user to use the design directly for various purposes, including laser cut instructions and architectural model production. With this format, we can make props or sets from 3D designs with PVC board or acrylic sheets.

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Also, I developed a paper model pattern for a low-poly tree and exported the data in DXF format.

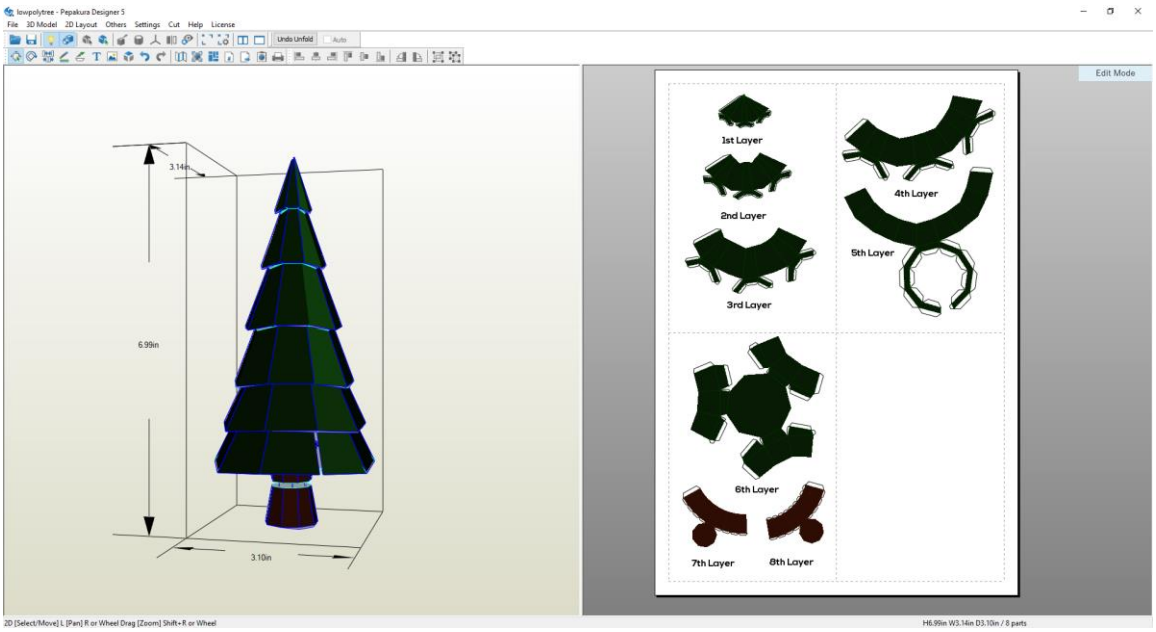

Figure 4.2: 3D Tree model in Pepakura designer

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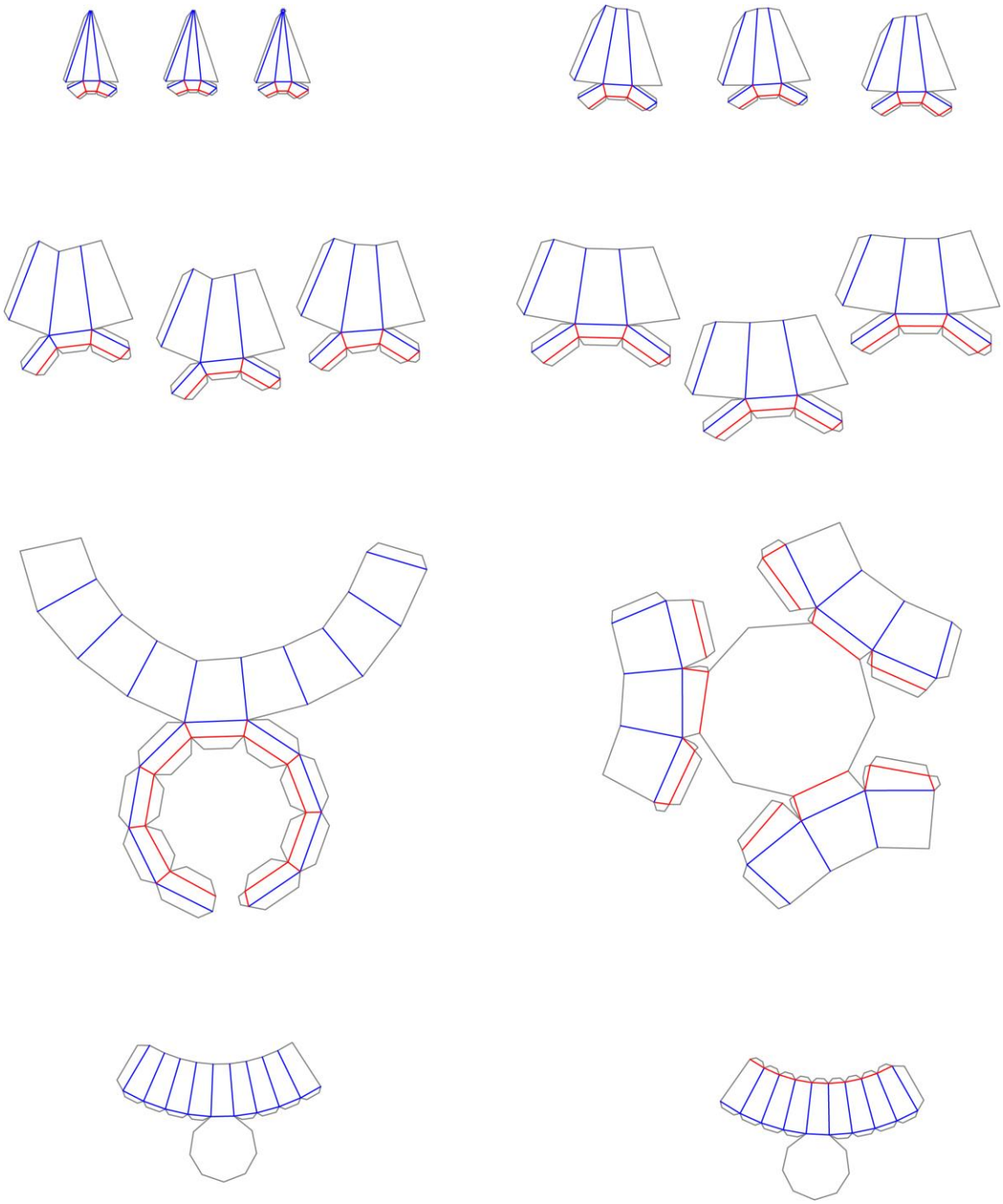

Figure 4.2: DXF file format of Tree's 2D layout

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CHAPTER 5: FUTURE SCOPE OF WORK & CONCLUSION

Pepakura is a software program that has gained popularity in recent years for its ability to create paper craft models from 3D designs. As technology continues to advance, it is likely that Pepakura will become even more sophisticated, with new features and capabilities being added over time.

5.1 FUTURE SCOPE OF WORK

In terms of market opportunities, the use of Pepakura in the papercraft industry is expected to grow, particularly in countries like Bangladesh where paper crafts have a rich tradition. Pepakura can be used to create a wide range of paper craft models, from small-scale decorations to large sculptures and props. With its easy-to-use interface and powerful 3D modeling capabilities, Pepakura is likely to become an increasingly valuable tool for Bangladeshi artisans and entrepreneurs who are looking to create unique and eye-catching paper craft products.

Pepakura can be an invaluable tool for costume designers and cosplay artists looking to create intricate and detailed costumes. By importing 3D models into Pepakura, users can generate a flattened version of the design that can be printed and used as a template for cutting out the various parts of the costume. This can save a significant amount of time and effort, as it eliminates the need to create a pattern from scratch. In addition, as more people become interested in cosplay and other forms of fan culture, the demand for high-quality paper craft models is likely to increase. Pepakura's ability to create detailed and accurate replicas of characters and props from popular media franchises makes it well-suited to meet this demand. With its potential to appeal to a wide range of consumers, Pepakura has a promising future in the Bangladeshi marketplace and beyond.

The ability to see the 3D model in Pepakura allows users to get a better understanding of how the various parts of the costume will fit together, which can be particularly useful for complex designs. Additionally, the flattened model generated by Pepakura includes folding lines and tabs, making it easier to assemble the various pieces of the costume accurately.

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Pepakura's ability to create precise and accurate paper models also makes it ideal for creating props and accessories for cosplay costumes. By creating a flattened version of the prop in Pepakura, users can create a template that can be used to cut out the various pieces of the prop from cardboard or other materials. This allows cosplay artists to create detailed and realistic props that can help bring their costumes to life. Overall, Pepakura is a powerful tool that can help costume designers and cosplay artists bring their creative visions to life in a precise and efficient manner.

Pepakura can also be a valuable tool for movie set designers who are looking to create intricate and detailed props and set pieces. By importing 3D models into Pepakura, designers can generate a flattened version of the design that can be printed and used to create precise paper replicas. This can be particularly useful for creating complex or large-scale props and set pieces, as the flattened model includes fold lines and tabs that make assembly easier and more accurate.

In addition to its use in movie set design, Pepakura can also be a fun and engaging activity for kids. The process of creating paper craft models from 3D designs can be an enjoyable and rewarding experience for children, as it allows them to see a physical representation of their creative efforts. This can be a great way to foster creativity and promote problem-solving skills, as children must figure out how to assemble the various parts of the model to create a cohesive whole.

Finished paper craft models can be used as decorations or even as toys, providing children with a tangible result of their efforts. Pepakura can also be used as an educational tool, allowing children to learn about geometry, spatial reasoning, and other STEM-related concepts in a fun and engaging way. Overall, Pepakura has the potential to be a versatile and valuable tool for both creative professionals and hobbyists, as well as a fun and engaging activity for kids.

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Pepakura can be a useful tool for architecture students who are looking to create accurate and detailed models of their designs. By importing 3D models into Pepakura, students can generate a flattened version of the design that can be printed and used to create a paper replica. This can be particularly useful for creating complex or intricate designs, as the flattened model includes fold lines and tabs that make assembly easier and more accurate.

Pepakura can also be used to create models at various scales, allowing students to create models that are representative of the size of the final building. By creating a physical model of their designs, students can better visualize and understand the spatial relationships between different parts of the building, which can be difficult to convey through 2D drawings alone.

Furthermore, Pepakura can be used to create detailed and accurate models of complex building elements, such as facades, roofs, and structural elements. By creating a paper model of these elements, students can better understand how they fit together and how they interact with other parts of the building.

Overall, Pepakura is a powerful tool that can help architecture students better understand and visualize their designs in a physical form. By creating accurate and detailed paper models, students can gain a deeper understanding of the spatial relationships between different parts of the building and better communicate their design ideas to others.

5.2 CONCLUSION

In conclusion, Pepakura is a versatile tool that has a wide range of applications in various fields, including costume design, movie set design, entertainment, and architecture. By importing 3D models into Pepakura, users can create flattened versions of the designs that can be printed and used as templates for creating accurate and detailed paper replicas.

For costume designers and cosplay artists, Pepakura can save time and effort by eliminating the need to create patterns from scratch and allowing users to better understand how the various parts of the costume fit together. For movie set designers,

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Pepakura can be a valuable tool for creating precise and accurate replicas of complex and intricate props and set pieces.

Moreover, Pepakura can be a fun and engaging activity for children, promoting creativity and problem-solving skills. In addition, architecture students can benefit from using Pepakura to create accurate and detailed physical models of their designs, allowing them to better understand the spatial relationships between different parts of the building.

Overall, Pepakura is a valuable tool that can enhance creativity, promote learning, and improve the efficiency of various creative processes. As technology continues to advance, it is likely that Pepakura and similar tools will play an increasingly important role in a wide range of fields, providing users with new and innovative ways to bring their ideas to life.

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Green line indicates connected edge Figure 4.1: Arranging parts Figure 4.1: Rotate mode Figure 4.1: Final Pattern Figure 4.1: Moving flaps Figure 4.1: Editing Flaps Figure 4.1: Setting Edge ID Figure 4.1: Printable Patterns Figure 4.2: Assembled head & leg parts Figure 4.2: Joined larger parts Figure 4.2: Complete Squirrel Paper model Figure 4.2: Two complete Squirrel Paper model Figure 4.2: High poly-count model in Pepakura designer Figure 4.2: 3D Tree model in Pepakura designer Figure 4.2: DXF file format of Tree's 2D layout 44 44 45 45 46 47 48 49 50 51 52 53 54 54 55 56 57 58 59 60 61 61 62 63 64 65 v CHAPTER 1: INTRODUCTION 1.1 INRODUCTION In this section, introductory review of the project is described. The whole project report has been divided into several sections, including the fundamental idea of my project, inspiration that driven me to do this and the goal that I want to achieve through this project, followed by the objectives and workflow to achieve the goal. 1.2 MOTIVATION Paper crafts are age old forms of art that employ paper as the preliminary artistic media to create three-dimensional objects. Card stocks and papers can be folded, cut, bent, curved, layered or molded through a wide range of techniques [1]. There are many variations within the paper art. Some common paper craft forms include: 01. Origami 02. Quilling 03. Kirigami 04. Painted paper collage 05. Decoupage 06. Paper mache 07. Paper Marbling Among the many forms of paper craft, Origami was my center of interest, and thus my topic of this project was inspired from Origami. The motivation behind this project was to produce a workflow to create three-dimensional paper model from 3D design, so anyone can prepare and create paper models from their own imagination. The Japanese word "origami" is made up of the smaller words "ori," which means to fold, and "kami," which means paper. Origami is the Japanese art of folding single sheets of paper into decorative figures. In modern days, the term "origami" is often generalized as an umbrella term for all paper-folding practices, regardless of their source or origin. It involves transforming a flat square sheet of paper into a sculpture through folding and sculpting techniques [2]. Traditionally, these designs begin with a square sheet of paper whose sides may be of different colors, prints, or patterns. Figure 1.2: Origami Paper Crane (Tsuru) by Icarus Mid Air [3] Types of Origami: 1. Action origami: In addition to the more common still-life origami, there are also moving object designs; origami can move [4]. 2. Modular origami: Modular origami consists of producing identical pieces that are subsequently pieced together to form a complete model. Although the individual pieces might be simple to make, the final assembly may be difficult to achieve [5]. 3. Wet-folding: An origami method called wet-folding creates structures with smooth curves rather than the typical geometric straight folds and flat surfaces. This is achieved by wetting, folding and drying the wet paper to fix the structure with curves that imitate a more lifelike pattern [6]. Figure 1.2: Wet-folding Origami by Hoang Tien Quyet [7] 4. Pureland origami: Pureland origami involves the restrictions that only simple mountain/valley folds are to be used, and all folds must have straightforward locations [8]. 5. Origami tessellations: Since 2000, the practice of origami tessellation became increasingly popular. Instead of a model or figurine, a group of figures that occupy a plane entirely and without overlaps is known as a tessellation. In origami tessellations, pleats are used to connect units such as twist folds together in a repeating fashion, creating an intricate pattern with a single sheet of paper [9]. Figure 1.2: Tessellation Origami by Alessandro Beber [10] 6. Kirigami: Kirigami is a Japanese term for paper cutting. This form of folding exclusively involves models with cuts. In contrast to traditional origami, kirigami involves cutting paper to achieve the final result. [11]. 7. Strip folding: Strip folding is a combination of folding and weaving paper strips. It is also called "origami fringe" [12]. 8. Teabag folding: Teabag folding is credited to Dutch artist Tiny van der Plas, who developed the technique in 1992 as a papercraft art for embellishing greeting cards [2]. 1.3 RESEARCH OBJECTIVE Computer aided design can be useful, creative and interesting because it allows user to carefully model, create and manipulate all aspects of a shape even at the smallest of scale to imitate reality and movements. 3D modeling is a subset of CAD (computer-aided design) that involves using

software to create three-dimensional representations of a figure, surface or original item. In general, 3D modeling improves the authenticity and efficiency of product designing. One may perform the following using 3D modeling programs: • Visualize final images before production • Make alterations and improvements to the designs. • Design, materials, and dimensions can be documented easily. 3D modeling is essentially the first step in the 3D printing process. [20]. Once the perfect model virtually built, the aspect to create a similar reality object comes to light. This has been made possible by CNC (Computer Numerical Controlled) machines for decades. These machines carve the shape from a solid block unit of material. Modern upgrade in this department is 3D printing which does a similar job to an Inkjet printer. But rather than ink, layers of melted plastics are placed on top of one another. Since 2005, the Replication Rapid Prototype (REPRAP) project initiated by the University of Bath (UK) made 3D printing available to hobbyist community throughout the world. Today, a REPRAP printer costs 500-1,500€ to build or buy a commercial one. Three-dimensional (3D) printing involves manufacturing process in which a physical object is produced from a digitally generated design by printing thin layers of material (like plastic) and then fusing the layers together. Some industries use 3D printing to create industrial prototypes and mass produce their products using custom scans, such as hearing aids and car manufacturers. 3D printing allows printing of more complex designs than traditional manufacturing processes with ease. Most traditional processes have design restrictions that do not limit 3D printing [21]. The technology can be used to repair toys, create spare parts, or create customized items like figurines or even transplants. While it is currently not as efficient for mass production, 3D printing technology is gradually evolving and has the potential to change the interface of both the manufacturing logistics and inventory management industries [22]. Figure 1.3: 3D Printing Models [23] While a variety of metals and polymers may be used to construct objects using 3D printing, the range of raw materials is not completely diverse. This is due to the fact that not all metals or plastics are easily manipulated by temperature to allow 3D printing. In addition, many of these materials might not be recycled and very few are safe for consumption and environment. PLA and ABS, the two most common types of plastics used for printing purpose are expensive and toxic. 3D printing also poses as a threat to environment. Materials like PLA can release particulates and other harmful chemicals into the air. Users can also get exposed to hazardous materials, such as metal powders, microparticles, solvents and other chemicals. It's also not a cost-effective method for massive production, as 3D printers themselves are expensive. 3D printers currently have confined print chambers with restrictions on the size of parts that can be printed. Anything bigger that restricted limit will need to be printed in separate parts and joined together after production. This can affect the production by increasing costs and time for larger parts, and manual labor is needed to join the parts together. Another issue with 3D printing is pos-processing. The majority of 3D printed items require human cleanup to remove support material, smooth the surface, and obtain the desired quality. Such methods include sanding, chemical soak & rinse, water jetting, air or heat drying and assembly. The amount of post processing required to get the finished product depends on factors such as the size of the parts, the printer itself, raw-materials, the intended application and the technology of 3D printing used for production. So, while 3D printing allows faster production of parts, post-processing may slow the speed of manufacture [24]. In contrast, two-dimensional printers use readily available, conventional materials like ink and paper for the production operations. Preparing a 2D printable template from a 3D model with textures can be printed and easily folded and assembled to create a 3D paper model in the real world. It's an eco-friendly & less time-consuming production process than 3D printing. The application of 3D modeling greatly assists in the designing and construction of paper models from digital sources. The source in question, for example, a video game, will have to be loaded into the computer. Several techniques can be used to extract the model, such as directly capturing it from the simulation or

exporting it from a model viewer into a useful file format. The methods of extracting the model are often selective for the subject and the tools available. Readability of file-formats including propriety ones could mean that a model viewer and exporter is restricted for the developer. Thus, using other tools to capture rendered 3D models and textures is often the only way to obtain them. In this case, the textures and the wireframe model might have to be arranged on a 3D program, such as 3DS MAX, SketchUp, Metasequoia, or Blender before exporting it to a program designed for papercraft model design generation, such as Pepakura Designer by Tama software or Dunreeb Cutout. From there the model can be refined to generate proper layout and construction tabs that can affect the overall construction process and final appearance of the model [13]. Paper crafts generated by Pepakura program takes a 3D model and flattens it to get a 2D template that can be printed, cut, trace on either foam or just use the printed paper and construct a 3D model physically. Pepakura is originally designed for paper crafting [25]. Paper is an underrated and underappreciated medium in multimedia technology. Many people enjoy developing models out of paper. Rather than just for showing printed information, paper can also be used for constructing physical paper models from virtual objects by means of glue and scissors. The availability of rich 3D model libraries of makes it desirable to automate this task. This requires generation of a planar cut-out sheet from a 3D model. The challenge is to produce a template that divides a given model into simpler, engaging parts that can be approximated by developable surfaces, thus having the property that they can be unfolded in a plane without being creased, stretched or torn. This type of designing can be used in similar applications including textured atlas generation and model production from sheets of material [26]. Figure 1.3: Papercraft modeling starts with a virtual 3D model [27] However, faces forming a model in 3D pose an issue upon unfolding. While 3D space has potential for a non-intersecting topology of faces, they tend to intersect easily in the planar projection of the cut-out sheet. Moreover, neighboring faces enclose such a close angle that it becomes difficult to cut out and glue together. Unfolding a virtual model requires selection of which edges of a 3D model to cut first. A carefully chosen order can be helpful to avoid the above-mentioned issues in many cases. However, finding the optimal order is an NP-complete problem. Large objects can be made with little effort using a simple printer, good quality paper and some glue. Paper models are popular for scale models of architecture, engineering disciplines, industrial design and other applications such as stage props, or production props where a small number of custom-made shapes are needed. Even in the virtual world, many users prefer to own a real 3D paper model of their avatar. To enhance structural integrity as paper models are fragile by nature, they can be reinforced with resin or fiberglass or carbon fiber to create a more durable structure. Fibers are applied inside to preserve the flat surface of the model as well [27]. The following requirements should be met for making paper-craft models: Approximation of each part by a developable surface. Ease of cutting and gluing between the boundaries of these approximations. Minimization of errors defined as a function of the difference between the original model and its paper-craft model. Minimal number of parts. Over the last decade, many methods have been proposed and developed for designing such segmenting meshes [26]. 1.4 RESEARCH QUESTION One of the most crucial components of research work is choosing the proper starting point. We encountered various crucial questions from data collection to the paper's conclusion, including Q.1 How will this study assist people? Q.2 How will this study serve the industry? Q.3 How much will people understand the value of 3D-based paper modeling? ©Daffodil International University 9 1.5 EXPECTED OUTCOME Although some paper modeling templates are available over the internet, they are very limited, produced and patented by certain artists and not accessible to everyone. The work process to create a unique design to produce a 3D paper model is not disclosed by majority of the artists, so it poses as a problem if one wants to create something on their own. To overcome this problem, my project focused on unveiling the pipeline to

produce a 3D paper model from a design, which can be followed to make customizable, unique models. 1.6 TARGET AUDIENCES 3D paper models can be a useful tool for learning as well as creative implementation. Target audience of this project includes- 1. Interactive toys for kids: paper folding to create their own 3D action figures that could aid the cognitive development of children. 2. Collector's exclusive figurines: 3D figurines of favorite characters can be exclusively designed and produced for collection. 3. Stop-motion props: Creating paper models can be an affordable alternative to conventional props used in stop-motion animation films. 4. Artists who want to create their own designs: The pipeline to create a 3D paper model would encourage artists to materialize their artistic views into reality. 1.7 REPORT'S LAYOUT For the purpose of presenting my work, this report is one of five distinct components. Each component of this paper is subdivided into a few sections, which makes it simpler to understand. Chapter 1: Introduction, it's the first section. This will enable it simpler for the reader to understand exactly what it is we will actually look into throughout the test. This section also outlines the study question, aims, and anticipated results. Chapter 2: Background, demonstrates the framework for the examination. earlier relevant studies were covered in this section. The divide between current work and related work is another thing we look at. Chapter 3: Research Methodology, we'll talk about the procedures and software needed for my workflow in this part. Chapter 4: Experimental Result & Discussion, the experimental outcomes and analysis of our study are covered in here. Chapter 5: Conclusion and Future Scope of Work is the last part of this report. Here, we discuss the conclusion of the project, its summary, our limitations, and how we should approach this task going forward. CHAPTER 2: BACKGROUND STUDY 2.1 INTRODUCTION In this chapter, we'll talk about paper models, their development over the years, as well as all the alterations that have occurred in between those changes. Regarding the magnitude of our issues what obstacles we would encounter in order to achieve this. 2.2 LITERATURE REVIEW Paper models also known as card models or paper figurines are models that are mostly made out of thick sheets of paper, cardboard, card stock, or foam. This may be considered a broad category containing card modeling and origami. To compare, Origami is the process of making a paper model by folding a single piece of paper without using glue or cutting, while card modeling is making scale models from sheets of cardstock on which the parts were printed, usually in full color. To assemble these parts, the design would be printed, cut out, folded, and glued. Paper modeling involves designing complex creations such as life-size characters, wearable armors, and weapon models. [13]. Figure 2.2: Paper Action Figurine [14] The first paper models are dated back to 17th Century Europe, and earliest records of commercial models were found in French toy catalogs during 1800s [15]. Printed card became common in the early 20th century. Called Paper-Card Modeling in Europe, it ranged from simple darts to complex miniature models of airplanes, ships and buildings. During World War II, materials were in supply shortage, and those that were available had restrictions of use. As necessity listed, toys were found at the bottom of the list. During this crisis, the U.S. toymakers decided to switch to toys and games made of paper and other nonstrategic materials. Even then, bizarre-colored paper models were produced due to shortages of printing ink. History of paper-model names an Englishman called Wallis Rigby. He moved his company to United States during the late 1930s with his company. Famous for his airplane, boat and train models made out of paper before WWII, he invented the Tab-and- Slot construction, which gained much publicity during the wartime. Since toys made of nonstrategic materials were on demand, Rigby's paper models gained more attention and were subsequently published as boxed sets and individual books. Moreover, individual aircraft models like Douglas Dauntless were published in newspapers in the colored Sunday Comic Section. Popularity of such products led to media coverage of Rigby, who demonstrated the steps in designing, building and flying his paper-model aircrafts. The impact of a material scarcity on premiums was also felt by cereal producers. General Mills offered simplified paper airplane

models as cereal prizes in 1944, emulating Rigby's designs. Mail in two box tops from Wheaties cereal and you received a pair of paper airplanes. Thousands of these models were distributed by General Mills as part of a nationwide competition. Backing this was a publicity campaign, showing Veterans in hospitals building the models. A contest held at Nebraska's Boy's Town garnered national Newsreel coverage, too. Several children and adults first tried model construction using paper airplanes. Following WWII, once the restrictions were lifted, usual materials like metal, wood and even newer plastics replaced the paper models rapidly for their longevity and appeal. Soon, paper-models disappeared from the U.S Market, and only a limited number of ©Daffodil International University 13 publishers continue to print paper-models [16]. Similarly, Micromodels [17], designed and produced in England from 1941 were very popular with over a hundred different models, including aircrafts, architecture and ships [18]. But as plastic models [19] became more commonly available, interest in paper-models decreased in competition. 2.3 SCOPE OF THE PROBLEM Our nation's technological development is quite far behind that of other third-world nations. On the other hand, in countries like the USA, UK, China, Japan children are more advanced in technology. They got introduced to 3D modeling and printing at a very early age from their schools. With the help of 3D printing, they are having the ability to make a variety of entertaining crafts and interactive toys. This is how they develop an early interest in 3D. Compared to children in other developed countries, children in our country are not very familiar with 3D technology. Because these 3D printing machines and their components are quite expensive. In contrast, paper and 2D printers are widely available and cheap in our country. 2D printers are available in most of our schools, colleges in our country nowadays. So, these 3D base paper figurine toys can be a good alternative for the school children to increase their interest in 3D. 2.4 CHALLENGES I had to overcome a number of obstacles during my studies in order to complete my research. The hardest part was that I couldn't identify enough literary works that related to my study topic. Second, figuring out the workflow was extremely difficult since there are very few paper modeling templates available online, they are made and trademarked by certain artists, and they are not available to everyone. The majority of artists don't reveal their creative method for producing original designs as 3D paper models, which presents a challenge for anyone looking to build anything on their own. CHAPTER 3: PROPOSED RESEARCH MODEL In this chapter, I will outline my study topic and the approach I employed to achieve my goal. 3.1 RESEARCH AREA & CONSTRUCTIONS I had to choose the techniques I wanted to use in my process before I could set up my pipeline. Before jumping into my experimental process, I studied my methods and materials. These are the following research are & contractions I’ve found related to my work: 1. 3D UNWRAP-UV TEXTURING A UV map represents the flat surface of the 3D model used for texture wrapping. Using 3D modeling software, a procedure known as UV unwrapping produces a UV map. The letters U and V in UV mapping refers to the axis of the 2D texture in the UV grid, where X, Y, and Z are used for the axis of 3D objects [28]. Figure 3.1: UV Mapping & Texturing [29] Texturing is another crucial stage of 3D modeling process. Texture can be defined as an image that is being projected on a flat surface of 3D object that gives the impression of a real object. This includes the subtle features of characters seen in 3D models, like wrinkles, hair strands and threads. These are products of textures applied by a 3D artist. Texturing can be explained as something similar to clothing a 3D model. Wrapping a 2- dimensional image around a 3-dimensional item and determining how lighting will affect it is 3D texturing. It is also known as PBR or Physical based rendering [30]. 2. PRINTER A printer is a machine made to take text and visual output from a computer and print it out on paper. Printers vary in size, speed, specificity, sophistication and cost [31]. 3D printing is the process of creating a 3D object from some material instead of paper, like plastic. In contrast, 2D printing simply refers to process of producing an image on paper. Both processes seem to be different. However, the technical operations behind

both types of printing have some strong resemblances [32]. There are six different kinds of printers. A3 printers, laser printers, LED printers, dot matrix printers, continuous ink printers, solid ink printers, and inkjet printers are among them. The most common and most used in the market are inkjet printers and laser printers. Inkjet printers are typically sold for day-to-day household use, while laser printers are often used for businesses purposes, but both can be used in either environment [33]. Inkjet printers reproduce a digital image command by spraying ink onto paper. These are the most common and popular types of personal printers. In comparison, Laser printers are used to produce higher-quality prints using laser beam. It involves passing a laser beam at high speed over a negatively charged drum, which defines an image. Color laser printers are usually found in professional settings [34]. Figure 3.1: 2D Printer [35] 3. TYPES OF PAPER For paper modeling, different papers are available and artists chose them according to their need. Examples include magazine paper, A4 offset paper, photo paper, inkjet paper, card paper and jasmine paper. Outcomes may vary based on paper and printing process used for the production. Different types of papers are sold at different market value. Recent view of paper market in Bangladesh is enlisted as below: A4 print cost 15-25tk/page A4 Inkjet 25tk/page A4 Photo paper 30tk/page A4 Magazine paper 25tk/page A4 Card paper 30-35tk/page 3.2 RESEARCH METHODLOGY The software I utilized for my research methodology are listed below: 1. AUTODESK MAYA Autodesk Maya, or Maya in short, is a 3D computer graphics application that was originally developed by Alias. Currently owned and developed by Autodesk, Maya runs on Windows, macOS and Linux. It is used for interactive 3D applications, animated projects and visual effects [36]. Figure 3.2: Logo of Autodesk Maya 2. RIZOM UV RizomUV is a dedicated UV mapping application with specialized strength for speed of workflow. It is more efficient than its peers, able unwrap, pack, and optimize in seconds. This effectively reduces the hours artists have to spend UV mapping in other applications into minutes [37]. Figure 3.2: Logo of RizomUV ©Daffodil International University 3. SUBSTANCE PAINTER Substance Painter is a dedicated 3D painting tool that can be compared as the 3D version of Adobe Photoshop for digital painting work. The main feature of Substance Painter is to texture modeling. It provides advanced masking and procedural texturing tools which allow creating textures that are much more difficult to achieve traditionally using purely 2D program like Photoshop [38]. The software is widely used in games and film visuals, as well as architecture, product design and fashion [39] . Figure 3.2: Logo of Substance Painter 4. PEPAKURA DESIGNER Pepakura Designer is a Windows application designed to make unfolded patterns from data of a 3D model. Pepakura Designer can automatically unfold 3D polygon-mesh models, and allow user to edit them to produce printable templates. The software is used to create real paper craft model templates from digital data [40]. Figure 3.2: Logo of Pepakura Designer CHAPTER 4: EXPERIMENTAL RESEARCH & DISCUSSION In this chapter, I'm going to give a complete description of my final project that I made for the final defense where I practically show my work method to complete this project. I've used two types of methods here. I'll show step by step how one can prepare a paper model layout from a 3D model Before starting this project, I researched about low poly and high poly modeling, how to UV Unwrap, how to texture, which method to choose, etc. Then I had to know what type of 3D model is suitable for my project. When it comes to 3D modeling, models can be categorized as either organic or hard surface. Whatever we design in a 3D application will either be a hard surface or an organic mesh [41]. Hard Surface models are best kind of models for paper modelling. But we can do also with organic mesh with low poly count. So, for this project, my pipeline will be: • Modelling • UV Unwrapping • Baking texture maps • Making 2D unfolded patterns from 3D data 4.1 EXPERIMENTAL METHODLOGY Before jumping into Pepakura Designer I first tried to create a layout using only Autodesk Maya and Substance Painter to understand the 2D layouts and what kind of problems I might face in combining them. In Autodesk Maya first, I used polygon cube to start making my model. My target was maintaining the low poly

count as much as possible. Figure 4.1: Polygonal cube to the model Figure 4.1: Model from four panel view After finishing my model, I unfolded my model by clicking the Unfold button in the Unfold section of the UV toolkit. Figure 4.1: UV Unwrapping process of the model After creating the UV mapping, I import my model into Substance Painter to create the texture map. Figure 4.1: Creating texture map in Substance Painter I added edge padding to spread the colors outward, creating a border of the same color around the UV shell. So that I can use those padding edges as flaps for my paper model. Then I baked 2D view texture to be used as may paper model layout. Figure 4.1: Baked 2D view texture After that I printed out the 2D texture layout into an A4 size paper and cut out the edge lines and folded the different pieces and glued them together to form the 3D shape of the actual model. This wasn't the satisfactory result I was expecting, so I tried to find other methods. Figure 4.1: Little Devil paper model In this part I will discuss how I use Pepakura Designer to create paper craft patterns from my low poly models. The starting point is to take a 3D model created in any 3D modeling software and use Pepakura Designer to create a 2D pattern that when cut, folded and glued creates a 3D paper model. Here I'm using a 3D model of a squirrel. I've UV Unwrap it in Rizom UV and textured in Substance Painter. In this process, I've opened the Fbx format of the model in Rizom UV. Figure 4.1: Importing the Squirrel model into Rizom UV I then specified the cutline edges by clicking them and hit C on keyboard to cut. Figure 4.1: Specifying the Cut Line Edges I hitted U on the keyboard to unwrap the UV after cutting. Figure 4.1: UV Unwrapping The UVs are then packed so they no longer overlap by pressing P on the keyboard. Figure 4.1: UV Packing Following that, I saved my file and opened it in Substance Painter to create a texture map. Figure 4.1: Importing the Fbx file into Substance Painter Then added a fill layer to fill color as layer wise. Figure 4.1: Adding fill layer Then added a black mask in fill layer. Figure 4.1: Adding black mask in fill layer Also, changed the base color according to my requirement. Figure 4.1: Changing base color I had filled my layers with the help of UV chunk selection. Figure 4.1: Polygon Fill Selection Figure 4.1: UV chunk fill Selection Then I started to fill different colors in different masking layers by selecting UV. Figure 4.1: Filling masking layers with color Figure 4.1: Layer wise different colors This was the output after filling all the colors. Figure 4.1: Squirrel with complete texture After filling all the colors, I tried to set up the light and then I baked the combined 2D view texture of my squirrel to use outside of Substance Painter. Baking the combined textures made up of the lightening, normal, diffuse, and other maps. The steps are right below with snaps: File > Export Texture Figure 4.1: Baking 2D Texture 1st step Output Templates > Plus button Figure 4.1: Baking 2D Texture 2nd step Name it any name Figure 4.1: Baking 2D Texture 3rd step Select RGB > From Converted > Drag 2D View > Place it on RGB > RGB Channel Figure 4.1: Baking 2D Texture 4th step Settings > Size > Highest Resolution Figure 4.1: Baking 2D Texture 5th step Output Template > Choose the one named > Figure 4.1: Baking 2D Texture 6th step Choose the output directory Figure 4.1: Baking 2D Texture 7th step Export and wait to bake. Figure 4.1: Baking 2D Texture 8th step Here is the baked combined 2D view texture of the squirrel. Figure 4.1: Baked 2D Texture of the Squirrel After completing these steps, I exported the squirrel 3D model as a wavefront obj file which is going to starting point for using Pepakura. With the program Pepakura Designer, we can unfold 3D mesh models to make paper craft creations. Unfolding required cutting the mesh into sections and flattening them. It is possible to automate this procedure or manually choose which edges should be trimmed first. The goal of automatic unfold is to create a pattern that requires extensive customization. The Basic steps in Pepakura are: • Open 3D model • Seam the edges/Define the edge to cut • Unfold the model • Adjusting the scale • Setting the page size • Editing pattern • Saving and printing the pattern Here I'm describing my work process in Pepakura Designer right below: 1. FLIPPING The first step is to open the squirrel model which saved in obj. format. Pepakura supports a few different file formats but obj works just fine. Figure 4.1: Opening 3D model in Pepakura Designer When the model is loaded and just model

coordinates appear the first thing is flip faces, which define the normal direction of the faces. Flip means turning the model inside out. The faces would appear dark gray if they needed flipping. Figure 4.1: Flipping in Pepakura Designer 2. FRONT BASE The next step to tell Pepakura where the front part of the model is. This is shown by red arrow here. The front of the model lines up, so it's okay. Figure 4.1: Define the front of the model in Pepakura Designer But if say the Squirrel's head was pointing to the yellow face then needed to click yellow in the dialog. Next thing is to tell Pepakura where the base of the model is, which is again shown by a red arrow. Here the Squirrel base and arrow all line up, so it's okay. If the Squirrel was rotated and the bottom was on the blue plane then needed to click blue in the dialog. Figure 4.1: Define the base of the model in Pepakura Designer 3. INVERT STEP In Pepakura Designer invert step which changes which side Pepakura interprets as left and which is right. This seems to affect the unfolding direction but since the Squirrel is symmetrical, it doesn't matter here. Figure 4.1: Invert step in Pepakura Designer 4. PAGE SIZE Pepakura has two views. A 3D view on the left and a 2D page view on the right. The page is where the pattern appears when once unfolded it and at present it shows a single empty page. Then need to set the page size before unfolding. This is a size of paper that going to print the pattern onto. Figure 4.1: Setting scale in Pepakura Designer The default is A4 portrait which is what I wanted and the rest of the settings are fine as well. Someone can just unfold the model at this point but the result will be a complicated pattern which will spend a long time cutting out and building. As we can see, the default on folding give shapes of different sizes which don't fit onto the pages. It's better to mark places on the 3D model which are meaningful features and which will make building easier. Figure 4.1: Output of Auto Unfold command 5. PAN ROTATE As an aside, the status bar at the bottom shows how to move the view around. Mouse wheel down for pan. Right mouse clicks and drag to rotate and wheel rotate the zoom. 6. OPEN EDGE In this case, I marked the main features on the model by going into 3D menu and selecting edit mode then open edge. This allow us to specify the edges to open. In edge operations hovering over the edge changes the color to green and left clicking marks it as an edge to be opened. Some edges are marked red and this shows that they are not connected to anything. Holes and extremities of the model are always red. If ever get mark and edge in error then it can be unmarked again by just left clicking again. Figure 4.1: Define edges for Cutline If model is symmetrical, someone can turn on pick symmetrical edge so that two corresponding edges are selected at the same time. This speeds things up considerably. Figure 4.1: Symmetrical edge selection 7. TEXTURE At this stage I had imported my 2D texture map from settings. Figure 4.1: Opening texture config dialog Figure 4.1: Selecting the texture map 8. SAVE Now at this time I saved my work. Pepakura projects are saved as pdo files which can be opened and printed using the free Pepakura viewer. There are a lot of decent pdo available on the internet. Figure 4.1: Saving pdo file 9. UNFOLD At this stage I had unfolded my Squirrel. Unfolding generates the pattern on the page view. If auto selected, Pepakura scales the parts to fit onto a single page. Otherwise anyone can specify the size of the model the way they want before unfolding it. I determined the squirrel depth to be 18 inches. Pepakura unfolded the model using the opened edges as a guide. I resized the views and zoom in for a closer look. Sometimes some paths might too large for the page. Figure 4.1: Generated unfolding pattern 10. FLAPS Others like the eye region have a lot of split edges and overlapping flaps where gluing and cutting would be difficult. On the pattern the flaps are shown here. The dash lines are where it needed to fold. There are two different types of fold line. A valley fold which has alternative different size dashes and a mountain fold which here has the same size dashing. Solid lines are where needed to cut out. If someone left click on the part in either the 2D or 3D views the part gets highlighted in the other view. Also, if we double left click on a face the face gets highlighted as well. Figure 4.1: Valley & Mountain fold lines on Flap 11. SCALE Before editing the parts I wanted to do a final check of the scale. I knew from measuring my 3D model that the depth part of the base opening is

18 inches. Which I've done so that it can be same as real size Squirrel. Pepakura provides a means to measure the distance between two points. So, I used it to check that my scaling was correct. The distance is 18 inches, so it's fine. If it was wrong, I can change the scale from the 2D menu. Figure 4.1: Scaling model to ensuring measurement 12. PARTS In this part I arranged the parts a bit. I tried to keep connected parts close to each other as possible. Started by selecting the parts and roughly arranging them. In 2D view clicked to select and drag to move. Also, the green stick can be used at the top to rotate the part. I worked my way around the model, selecting parts and roughly grouping them together. Figure 4.1: Keeping connected parts close to each other 13. FLAP SIZE Before editing, it's important to decide on the size of the flaps we're going to use for the model. Smaller models need smaller flaps but this makes gluing a little more difficult. By clicking right in the 2D view and Edit Flaps can be selected. From the dialog box we need to select shape and set the height to what we want. Applying this to all the flaps, we'll notice that all of the flaps get a little larger. Figure 4.1: Editing Flap size 14. JOIN & DISJOIN FACE We need to take each part and turn starting with the one we'll assemble first. In this case, I've chosen the eye region of the Squirrel. The problem with this part is that there are a lot of cuts and small flaps due to the angles between the faces. The aim is to turn edges into falls where I could and to make the parts as large as possible without losing the features too much and keeping it on one page. Then, I went into join disjoin face mode. Hovering over the 3D model shows the edges and folds being selected. Hovering over the part on the pattern does the same. Figure 4.1: Join & Disjoin Face mode Left clicking will either cut a fold or seal a cut as we can see. Depending on the face angles sealing a coat may cause a fold elsewhere to open. With the eye, I had chosen to separate the inner part from the outer part to make gluing easier. I moved them slightly to keep them together. Rotated using the green stick at the top of the selection. 15. CONNECTING EDGES Hovering over a connected edge will allow us to see a green line which shows which of the edges is connected to. Left clicking forces them to join in the direction indicated by the arrow. I tended to work on the 3D view. I continued on like this resize and to create a large piece but with no overlapping flaps and no split faces until the model is complete. Since this model is symmetrical, I did one side first and then just repeat for the other side. Figure 4.1: Green line indicates connected edge 16. ARRANGING PARTS The next step is to arrange the parts to minimize the number of pages used. On symmetrical models it is helpful to keep the left and right side separate even if this takes more pages and also keeping connected parts together. This makes it easier to organize and assemble the parts after they've been cut out. Since I ended up with two pairs of parts which are in some sort of order. I started by fitting the largest parts first and then using the smaller parts to fill in the gaps. Then picked select and move mod to grab and rotate the parts into position. Tried to align long straight edges with the edge of the page leaving a small gap between. The dashed lines represent the page margin. We can also change this in the print and paper settings but the defaults worked fine for me. There are a couple of features which Pepakura provides to help with arranging parts. One is a grid and snap to grid feature which is set from the 2D menu. Snapping works using the bounding box of the part and the grid. Figure 4.1: Arranging parts 17. ROTATE MODE Another thing for aligning is to use rotate mode. If we double click on an edge and it has an angle of less than 45 degrees then it rotates to horizontal alignment and if greater than 45 degrees it rotates to vertical alignment. Figure 4.1: Rotate mode 18. LAYOUT I continued to arrange the parts until I became happy with the overall layout. 19. PATTERN As we can see, the pattern has been separated into eleven pages. I tried to keep connected parts together wherever possible. Figure 4.1: Final Pattern 20. MOVE FLAPS The next step is to move some flaps around. I wanted to aim for a part having a flap on every other edge so that the two parts fit together better when being assembled. Parts where there are continuous flaps fitting onto another with a continuous edge are more difficult to align accurately when you're building the model. Some of the flaps on the outside should be moved. Then I went for Edit

Flaps and select Position. I hovered over the edge to see where it connects and which made sense to me, I kept clicking to move the flap. Figure 4.1: Moving flaps 21. EDIT FLAPS Sometimes moving a flap causes the part to overlap another one. So, I had to rearrange them a little as well. I continued to edit the flaps until I were happy with the flaps spacing. There might be some parts where the flaps are not perfect since there will be an odd number of edges in places. Figure 4.1: Editing Flaps 22. SET FONT SIZE The final stage is to switch on the edge numbers and to set the font size. I would switch off the texture if I go for a plain pattern. But for my model I wanted to print out with texture. In case we go for plain pattern we need to go to the 2D menu and select Show Edge ID to show the edge numbers. As we can see, the same number appears on the edge and its correspondent opposite edge with the flap. Edges with the same number are fixed together when the model has been assembled. Figure 4.1: Setting Edge ID 23. PRINT TO PDF Now, the final thing was to save my work and print the pattern. I prefer to print to a pdf first and then open the pdf in Acrobat Reader to examine the pattern for any problems. 24. PRINT THE PATTERNS The things I looked for the parts which overlap pages and making sure that there is adequate spacing between the parts. The final step is to printing the pattern and building it. At this stage, we're done to transform our 3D model to a 2D pattern. Figure 4.1: Printable Patterns 4.2 RESULT & ANALYSIS I printed my layout on magazine paper once I had finished it. To achieve realistic color and gloss, I preferred laser printing. Then I started cutting the pieces from the pattern, folding and assembling all the pieces together. I began gluing the parts which has little pieces. Figure 4.2: Assembled head & leg parts I eventually started to join the larger parts in this manner. Figure 4.2: Joined larger parts And in this way, I've finished my entire model. Figure 4.2: Complete Squirrel Paper model Figure 4.2: Two complete Squirrel Paper model I tried using a model with high poly-count, but the outcomes weren't great. After unfolding in Pepakura Designer the outcome was something like this: Figure 4.2: High poly-count model in Pepakura designer Pepakura Designer has requirements for creating paper model layouts from a 3D model. That model has to be with a cleaner topology and low poly counts as much as possible. Otherwise, that model requires retopology. An interesting feature about Pepakura is it allows data to be saved in DXF format. This format is a useful tool which allows user to use the design directly for various purposes, including laser cut instructions and architectural model production. With this format, we can make props or sets from 3D designs with PVC board or acrylic sheets. Also, I developed a paper model pattern for a low-poly tree and exported the data in DXF format. Figure 4.2: 3D Tree model in Pepakura designer Figure 4.2: DXF file format of Tree's 2D layout CHAPTER 5: FUTURE SCOPE OF WORK & CONCLUSION Pepakura is a software program that has gained popularity in recent years for its ability to create paper craft models from 3D designs. As technology continues to advance, it is likely that Pepakura will become even more sophisticated, with new features and capabilities being added over time. 5.1 FUTURE SCOPE OF WORK In terms of market opportunities, the use of Pepakura in the papercraft industry is expected to grow, particularly in countries like Bangladesh where paper crafts have a rich tradition. Pepakura can be used to create a wide range of paper craft models, from small- scale decorations to large sculptures and props. With its easy-to-use interface and powerful 3D modeling capabilities, Pepakura is likely to become an increasingly valuable tool for Bangladeshi artisans and entrepreneurs who are looking to create unique and eye- catching paper craft products. Pepakura can be an invaluable tool for costume designers and cosplay artists looking to create intricate and detailed costumes. By importing 3D models into Pepakura, users can generate a flattened version of the design that can be printed and used as a template for cutting out the various parts of the costume. This can save a significant amount of time and effort, as it eliminates the need to create a pattern from scratch. In addition, as more people become interested in cosplay and other forms of fan culture, the demand for high- quality paper craft models is likely to increase. Pepakura's ability to create detailed and accurate replicas of

characters and props from popular media franchises makes it well- suited to meet this demand. With its potential to appeal to a wide range of consumers, Pepakura has a promising future in the Bangladeshi marketplace and beyond. The ability to see the 3D model in Pepakura allows users to get a better understanding of how the various parts of the costume will fit together, which can be particularly useful for complex designs. Additionally, the flattened model generated by Pepakura includes folding lines and tabs, making it easier to assemble the various pieces of the costume accurately. Pepakura's ability to create precise and accurate paper models also makes it ideal for creating props and accessories for cosplay costumes. By creating a flattened version of the prop in Pepakura, users can create a template that can be used to cut out the various pieces of the prop from cardboard or other materials. This allows cosplay artists to create detailed and realistic props that can help bring their costumes to life. Overall, Pepakura is a powerful tool that can help costume designers and cosplay artists bring their creative visions to life in a precise and efficient manner. Pepakura can also be a valuable tool for movie set designers who are looking to create intricate and detailed props and set pieces. By importing 3D models into Pepakura, designers can generate a flattened version of the design that can be printed and used to create precise paper replicas. This can be particularly useful for creating complex or large-scale props and set pieces, as the flattened model includes fold lines and tabs that make assembly easier and more accurate. In addition to its use in movie set design, Pepakura can also be a fun and engaging activity for kids. The process of creating paper craft models from 3D designs can be an enjoyable and rewarding experience for children, as it allows them to see a physical representation of their creative efforts. This can be a great way to foster creativity and promote problem-solving skills, as children must figure out how to assemble the various parts of the model to create a cohesive whole. Finished paper craft models can be used as decorations or even as toys, providing children with a tangible result of their efforts. Pepakura can also be used as an educational tool, allowing children to learn about geometry, spatial reasoning, and other STEM-related concepts in a fun and engaging way. Overall, Pepakura has the potential to be a versatile and valuable tool for both creative professionals and hobbyists, as well as a fun and engaging activity for kids. Pepakura can be a useful tool for architecture students who are looking to create accurate and detailed models of their designs. By importing 3D models into Pepakura, students can generate a flattened version of the design that can be printed and used to create a paper replica. This can be particularly useful for creating complex or intricate designs, as the flattened model includes fold lines and tabs that make assembly easier and more accurate. Pepakura can also be used to create models at various scales, allowing students to create models that are representative of the size of the final building. By creating a physical model of their designs, students can better visualize and understand the spatial relationships between different parts of the building, which can be difficult to convey through 2D drawings alone. Furthermore, Pepakura can be used to create detailed and accurate models of complex building elements, such as facades, roofs, and structural elements. By creating a paper model of these elements, students can better understand how they fit together and how they interact with other parts of the building. Overall, Pepakura is a powerful tool that can help architecture students better understand and visualize their designs in a physical form. By creating accurate and detailed paper models, students can gain a deeper understanding of the spatial relationships between different parts of the building and better communicate their design ideas to others. 5.2 CONCLUSION In conclusion, Pepakura is a versatile tool that has a wide range of applications in various fields, including costume design, movie set design, entertainment, and architecture. By importing 3D models into Pepakura, users can create flattened versions of the designs that can be printed and used as templates for creating accurate and detailed paper replicas. For costume designers and cosplay artists, Pepakura can save time and effort by eliminating the need to create patterns from scratch and allowing users to better understand how the various parts of

the costume fit together. For movie set designers, ©Daffodil International University 68 Pepakura can be a valuable tool for creating precise and accurate replicas of complex and intricate props and set pieces. Moreover, Pepakura can be a fun and engaging activity for children, promoting creativity and problem-solving skills. In addition, architecture students can benefit from using Pepakura to create accurate and detailed physical models of their designs, allowing them to better understand the spatial relationships between different parts of the building. Overall, Pepakura is a valuable tool that can enhance creativity, promote learning, and improve the efficiency of various creative processes. As technology continues to advance, it is likely that Pepakura and similar tools will play an increasingly important role in a wide range of fields, providing users with new and innovative ways to bring their ideas to life. REFERENCES [1] "Paper Craft - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Paper_craft >>, last accessed on Jan. 06, 2023 at 8:43 pm. [2] "Origami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Origami >>, last accessed on Jan. 06, 2023 at 8:54 pm. [3] "Icarus Mid Air – Instagram", retrieved from << https://www.instagram.com/icarus.mid.air/ >>, last accessed on Jan. 06, 2023 at 9:05 pm. [4] "Action Origami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Action_origami >>, last accessed on Jan. 06, 2023 at 9:07 pm. [5] "Modular Origami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Modular_origami >>, last accessed on Jan. 06, 2023 at 9:09 pm. [6] "Wet-folding Origami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Wet-folding >>, last accessed on Jan. 06, 2023 at 9:10 pm. [7] "Origami Artist Creates Charming Animals with Unique Wet Folding Technique – My Modern Met", retrieved from << https://mymodernmet.com/hoang-tien-quyet-wet-folding-origami/ >>, last accessed on Jan. 06, 2023 at 9:25 pm. [8] "Pureland Origami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Pureland_origami >>, last accessed on Jan. 06, 2023 at 9:25 pm. [9] "Tesselation Origami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Tessellation >>, last accessed on Jan. 06, 2023 at 9:26 pm. [10] "Alessandro Beber: Origami Art & Design – Facebook", retrieved from << https://www.facebook.com/AleBeberOrigamiDesign/posts/pfbid02ZZefHgN2sWomgBBMbq9ned7TbqxRjM2dEY8cobkVQQxtPwBsD83E29nZGJ2abSrCl >>, last accessed on Jan. 06, 2023 at 9:27 pm. [11] "Kirigami - Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Kirigami >>, last accessed on Jan. 06, 2023 at 9:27 pm. [12] "Strip Folding - Origami Resource Center", retrieved from << https://origami-resource- center.com/strip-folding/ >>, last accessed on Jan. 06, 2023 at 9:32 pm. [13] "Paper Model – Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Paper_model?fbclid=IwAR07nVAaeKRXB4wM3qhI4mctnOvDyBDQodk9c4XZvZvhRVVb5Uh0p01NiaU >>, last accessed on Jan. 06, 2023 at 9:35 pm. [14] "Craft Master "Z" – Facebook", retrieved from << https://www.facebook.com/CraftMasterZee/posts/pfbid0Vrci1rBxLiuvq69V2vxEq2yBsp3Vkv98TrvdDD5mwuuq7igaySKZgnAWqxfiCR9al >>, last accessed on Jan. 06, 2023 at 9:32 pm. [15] "Nastawnia Bramowa Paper Model", retrieved from << https://collections.vam.ac.uk/item/O131181/nastawnia-bramowa-paper-model-swiat/ >>, last accessed on Jan. 06, 2023 at 9:37 pm. [16] Philip Koopman, Sr. "A brief history of paper models", retrieved from << https://users.ece.cmu.edu/~koopman/airplanes/history.html >>, last accessed on Jan. 06, 2023 at 10:13 pm. [17] "Micromodel – Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Micromodel >>, last accessed on Jan. 06, 2023 at 10:15 pm. [18] "The history of Micromodels Ltd and Modelcraft Ltd miniature cut-out kits", retrieved from << https://web.archive.org/web/20160313125700/http://www.worldofmicromodels.com/micromodels-history.html >>, last accessed on Jan. 06, 2023 at 10:16 pm. [19] "Plastic model – Wikipedia", retrieved from << https://en.wikipedia.org/wiki/Plastic_model >>, last accessed on Jan. 06, 2023 at 10:16 pm. [20] Pallavi Mahajan (2021, December 7) "10 REASONS WHY 3D MODELING IS IMPORTANT IN THE

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