Preservation of Indonesian Traditional Theater Art using 3DCG Animation Technology

3DCG アニメーション技術を利用したインドネシアの伝統的な演劇芸術の保存

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Presented to Division of Industrial Art

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In partial fulfillment of requirement for degree of Doctor of Philosophy

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2015

Abstract

There are various types of traditional theater art called Wayang in Indonesia. One of them is Wayang Beber of Pacitan, which originated in the 17th century and has a long history of over 400 years. Despite the precious value of these art works as cultural, historical, and religious heritage of Indonesia, their preservation is currently in a critical condition. Because of the humid climate of Indonesia it is hard to keep pictures in a good condition, and in addition, the country is experiencing a dramatic decrease in the number of artists to draw them, lack of budget for preservation, and lack of overall national interest in the preservation of Wayang Beber of Pacitan. It is feared that without a quick action, Wayang Beber of Pacitan could be lost in the near future. The purpose of this research is to preserve the Wayang Beber of Pacitan in a reasonable manner, so that Indonesian cultural heritage survives eternally.

In order to solve the problems, the author proposes an application of 3-Dimensional Computer Graphics (3DCG) technology as a tool to reproduce and save the art digitally. The author then develops a 3DCG system specifically to generate Wayang Beber of Pacitan art works. As an example, some digital art reproduction works of Wayang Beber of Pacitan are generated using the proposed system.

This thesis consists of 6 chapters:

Chapter 1 describes background, scope, and objectives of the research. This chapter also provides literature survey related to digital preservation of cultural heritage, and specific non-photorealistic CG techniques such as silhouette rendering, pattern generation.

Chapter 2 discusses the research to compile archives of Wayang Beber of Pacitan. This research is performed by surveying related research works, observing the actual artwork and gathering data from interviews. The results of this survey are used as a basis for analyzing the visual style of Wayang Beber. After the identification of characteristics of the visual style, details of the required method for converting the pictures into 3DCG animation are determined. The original Wayang Beber is composed of many parts. It is difficult to create parts one by one in 3DCG, therefore a method that can generate the picture semi-automatically is considered to be used.

Chapter 3 discusses the development of an outline shader. This shader is used to simulate outlines of Wayang Beber pictures on a 3DCG model. Outlines of Wayang Beber have some typical characteristics, such as expressive brushstrokes and variations in thicknesses. To produce an outline with these characteristics, a shader that incorporates object-based silhouette detection and a non-uniform point displacement algorithm is proposed.

Chapter 4 discusses the development of the shader to generate ornamentation for rendering Wayang Beber characters' textiles patterns. The characters of Wayang Beber have many

characteristic patterns on their textiles. These patterns would require plenty of hard work during the 3DCG animation production of Wayang Beber. This research proposes a semi-automatic system utilizing a shader that uses procedural pattern generation based on shape grammars. Using this system, artists can easily create and modify details of the pattern including shape, size, quantity, color, and arrangement.

Chapter 5 discusses key pose extraction and interpolation of in-between frames for animating CG characters made from Wayang Beber of Pacitan paintings. A Wayang Beber painting is a still image that does not have motion from it. Therefore, it appears that it would be very difficult to make a cartoon movie. However, P. Tabrani showed in his study that the essence of motion does exist in these historical paintings. In this research, a new technique was established using the theory developed in Tabrani's study and the author have succeeded in extracting key poses from Wayang Beber of Pacitan works. Next, in-between frames are needed for the purpose of making a cartoon movie from the extracted key poses. The interpolation in this research is based on the principles of Wayang motion. The principles are derived from movements in other types of Wayang performances, such as Wayang Orang and Wayang Kulit. Using the method proposed in this research, the key frames and in-between frames for animating the characters are able to be provided adequately.

Chapter 6 contains the conclusion and the summary of this research. The quality of digital reproductions of traditional drawings using this 3DCG system and the usability of this system are checked and evaluated. Using the methods proposed in this research, it is possible to create 3DCG animations from other types of Wayang Beber. The author intends to propose this 3DCG system to the Indonesian government as a tool for the preservation of traditional theater art in order that this research can contribute to the survival of cultural heritages in Indonesia.

Keyword: Non-photorealistic animation, computer graphic, Wayang Beber, digital preservation of Indonesian heritage

概要

インドネシアにはワヤンと呼ばれる様々な種類の伝統的な演劇芸術がある。その中の 1 つが、絵巻を用いたワヤンベベルである。ワヤンベベルは 17 世紀に発生し 400 年以上の長い歴史を持っており、インドネシアの文化的、歴史的、および宗教的遺産として大変貴重であるにもかかわらず、それらの保存は現在、危機的な状態にある。インドネシアの高温かつ湿潤な気候のため、これらの絵画を良好な状態で維持することは困難である。加えて、それらを修復・描画するための芸術家の数が劇的に減少しており、保存のための予算も不足している。また、ワヤンベベルの保存に対する国全体の意識の欠如もある。今、ワヤンベベルの保存に対する迅速な行動が行われなければ、近い将来にそれらが失われることが懸念されている。本研究の目的は、現実的な方法で、伝統的な演劇芸術を維持保存することであり、その結果として、インドネシアの文化遺産を恒久的に存続させる事にある。

上記の課題を解決するために、本論文の著者は、ワヤンベベルの作品をデジタルアートとして保存するためのツールとして 3 次元コンピュータグラフィックス（3DCG）技術の適用を提案し、具体的に 3DCG システムの開発を行った。そして本研究の成果を検証するために、デジタルアートによるワヤンベベルパチタンの再現作品を、上記の 3DCG システムを使用して生成した。

本博士論文は 6 章から構成されている。

第 1 章は、本研究の背景や目的について述べると共に、文化遺産のデジタルな保存、シルエットレンダリングやパターン生成といった非写実的表現のＣＧ技術に関係する文献調査を行った。

第 2 章では、ワヤンベベルパチタンに関する資料収集について述べる。ここでは、ワヤンベベルに関する関連研究の調査、実際のアートワークの観察、パフォーマーからのインタビューデータの収集などを実施した。この調査の結果は、ワヤンベベルのビジュアルなスタイルを分析するための基礎として用いられた。ビジュアルなスタイルの特徴を抽出した後に、画像を 3DCG アニメーションに変換する手法の詳細を決定した。オリジナルのワヤンベベルは、多くのパーツにより構成されており、3DCG ですべてのパーツを一つずつ作ることは難しいため、画像を半自動的に生成する手法を検討した。

第 3 章は、輪郭線シェーダーの開発について述べる。このシェーダーは、ワヤンベベル画像の輪郭線を 3DCG モデルによってシミュレーションするために使用される。ワヤンベベルの輪郭線は、表現豊かな筆づかいや太さのバリエーションなど、いくつかの典型的な特徴を持っている。これらの特徴を生かした輪郭線を生み出すために、オブジェクトベースのシルエット検出や、不均一なポイントディスプレイスメントアルゴリズムを含んだシェーダーを構築した。

第 4 章は、ワヤンベベルのキャラクターがまとっている布地パターンを生成するためのシェーダーについて述べる。ワヤンベベルのキャラクターの着衣は多くのきわだったパターンを持つ。これらの装飾は、ワヤンベベルの 3DCG アニメーション制作工程において、非常に多くの作業を必要とす

る。本研究では、形状の規則に基づいて手続き的にパターンを半自動で発生させるシェーダーシステムを提案した。本システムを使うことによって、アーティストは、形、サイズ、量、色、および配置を含むパターンの詳細を簡単に生成し調整することができる。

第 5 章は、ワヤンベベルのＣＧキャラクターをアニメーション化するためのキーポーズ抽出と中割補間について述べる。ワヤンベベルパチタンは静止画なので動きが無い。従って、アニメーションを作成することは非常に難しい作業となる。しかし、P. Tabrani はその研究の中で、古い絵画の中には動きの成分が存在する事を明らかにした。本研究ではこの理論を元に手法を確立し、ワヤンベベルパチタンの中からキーポーズを抽出する事に成功した。次に、抽出されたキーポーズをアニメーション化するためには、中割補間したフレームが必要となる。本研究における補間はワヤンの動きの原理に基づいており、この原理はワヤンオランやワヤンクリットといった別のタイプのワヤンのパフォーマンスでの動きから導き出されている。本研究において提案された手法を使う事により、キャラクターをアニメーション化するためのキーポーズ生成および中割補間が、適切に提供される。

第 6 章は、この研究の結論および要約である。本 3DCG システムを使用して、オリジナル画像からデジタル作品を再現した場合のクォリティ、および本システムのユーザビリティについて確認と評価がなされた。本研究で提案される手法は、他のタイプのワヤンベベルから 3DCG アニメーションを作成することも可能である。著者は、本研究がインドネシアの文化的な遺産の保存作業に寄与できるように、伝統的な演劇芸術の保存のためのツールとして、この 3DCG システムをインドネシア政府に提案することを計画している。

キーワード：ノンフォトリアリスティック・アニメーション，コンピュータグラフィックス，ワヤンベベル，インドネシア遺産のデジタル保存

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Chapter 1.
Introduction

1. 1 Background

The purpose of this thesis is to find methods for developing 3DCG animation, which will be used to preserve Indonesian traditional theater art. In this thesis, theater art is defined as a collaborative form of art that uses live performers to present an experience of a real or imagined event in front of live audiences in a specific place. Theater art is a combination of several art forms such as performance art, visual art, and music. There are various types of traditional theater art in Indonesia. One of them is called Wayang. Wayang is a traditional theater art that incorporates particular visual media such as stone relief, painting, leather puppet, or human performance to convey stories.

Wayang can be found throughout Southeast Asian regions. In Indonesia, particularly in Java, various types of Wayang have existed for centuries. They are classified based on the media which are used in the performances. The most popular type of Wayang in Indonesia today is Wayang Kulit Purwa. Wayang Kulit Purwa is performed using an articulated leather puppet. In its performance, the puppets are shown as silhouettes, so that, it is often called as shadow puppets. Wayang Kulit Purwa is an example of a Wayang type that is preserved properly. New puppets are still produced and performances are held regularly. Regeneration of Wayang Kulit Purwa artists and storytellers goes very well.

Other types of Wayang have different conditions, for example, a type of Wayang called Wayang Beber which is almost neglected. Only a few people know about it. Wayang Beber is a type of Wayang that is performed using a series of painted scrolls (see Figure 1). Nowadays, Wayang Beber performances are difficult to be found.

Only two sets of Wayang Beber paintings still exist and their condition is very poor. Without a proper preservation effort, Wayang Beber will be lost in the near future. The preservation of Wayang Beber should become a priority. The preservation of Wayang Beber is the purpose of this thesis. This thesis focuses on one type of Wayang Beber called Wayang Beber of Pacitan.

1.1.1 Wayang Beber of Pacitan

Wayang Beber of Pacitan is found in a town named Pacitan in East Java. The word *Beber* means unfold in English. In the performance, a storyteller unfolds painted scrolls one by one while narrating the story. As mentioned by Perwiranto [1], in a normal condition, a performance of Wayang Beber of Pacitan is about 90 minutes long. It is accompanied by a simple music arrangement using traditional musical instruments such as *Gong, Kenong, Kendang* dan *Rebab*.

Wayang Beber of Pacitan tells a story of *Jaka Kembang Kuning*, which is a chronicle of a king and a warrior from ancient Javanese Kingdom of Kediri. The story is painted on six scrolls of a Javanese traditional paper called *Daluang*. The size of Wayang Beber of Pacitan scroll is 75cm x 380cm. Each scroll depicts four scenes of story (See Figure 2).

Figure 1. Wayang Beber performance[1] [2]

[1] ©Kassian Chepas, KITLV Press

Figure 2. First Scroll of Wayang Beber of Pacitan[2] [3]

Wayang Beber of Pacitan painting has a distinctive visual style. Each scene has a complex composition with decorative patterns and polychromatic colors. The composition is flat and almost symmetrical without an empty space. The painting also has a typical way to depict a human figure. Most of the figures seem identical; they have thin proportion with long limbs and a long neck.

Wayang Beber of Pacitan is kept and inherited by generations of storytellers in Pacitan. Currently it is kept by the 14th generation. Wayang Beber of Pacitan is seen as a sacred relic by the local communities and only performed in special occasions to pray for safety and prosperity [4]

1.1.2 Importance of Wayang Beber of Pacitan

Scholarly researches in the field have emphasized the importance of Wayang Beber of Pacitan for Indonesia. Warto asserted that there are three values of Wayang Beber of Pacitan [5]:

1. Wayang Beber is an important heritage for Indonesia. Its value has been recognized by UNESCO. In 2003 it was included as Indonesia's intangible cultural heritage, so that its preservation should become a priority [6].
2. As an intangible cultural heritage, Wayang Beber of Pacitan embodies local wisdoms and knowledge. As stated by Koesoemadinata, Wayang arts carry multidimensional knowledge such as theatrical, literature, philosophy, moral education, visual arts, and crafts [7]. These are the important values of Wayang

[2] ©Saji

Beber. The art, philosophy, and moral knowledge are significant factors to establish a cultural identity of Indonesian. As stated by UNESCO, the intangible cultural heritage is an important factor in maintaining cultural diversity in the face of growing globalization.

3. Wayang Beber of Pacitan has social and economic values. Wayang Beber of Pacitan is a valuable asset for Indonesian tourism. It is also a valuable source for Indonesian creative industry. The creative industry is considered as a booster of Indonesia economy in the future. In this industry, incorporating local content in a new product is important to create identity and unique selling point. For Indonesia, the feasible sources for the local content are its cultural heritages.

The importance of Wayang Beber is also acknowledged in the field of media studies. Wayang Beber is considered as an early visual media. As stated by Huhtamo [8], although there is no direct evidence, scholars such as Oliver Cook and Harold Foster considered that Wayang Beber has influenced Western moving image media in 19th century. Foster even categorized it as a primitive cinema.

1.1.3 Preservation of Wayang Beber of Pacitan

Wayang Beber can be considered as a rare traditional art form. There were six Wayang Beber in Java, but only two still exist, those are Wayang Beber of Pacitan and Wayang Beber of Wonosari. These days, both of them are unpopular. Unlike other types of Wayang, Wayang Beber is kept in rural areas of Java. They are only recognized by a small community there. The Wayang Museum in Jakarta, Indonesia has a set of Wayang Beber of Pacitan replicas. However the museum rarely holds performances. Without a performance, people cannot understand the true form of Wayang Beber of Pacitan.

As mentioned before, presently, the condition of Wayang Beber original paintings is very poor. Restoration of the painting is difficult to be done because Wayang Beber of Pacitan is still considered as a sacred relic which is not allowed to be taken out from Pacitan. In addition, the country is also experiencing a dramatic decrease in the number of artists to draw them. Without a quick action Wayang Beber of Pacitan can be lost in the near future. Preservation effort is urgently needed, although it will encounter some difficulties. One of them is the lack of interest of Indonesian young generations in Wayang. As described by Wardani and Widiastuti [9] several types of Wayang arts have been neglected and forgotten. Indonesian young generations often think of Wayang as performance arts for the old. The performances are often performed in unattractive places for them. Most of Wayang performances have a very long duration; they make young viewers feel bored. Moreover, there is lack of

support from the government for preserving and promoting Wayang.

Nevertheless, preservation of Wayang Beber of Pacitan has been done before. The first effort was done in the early 20th century. At that time, King Mangkunegaran VII ordered a painter named Widosupomo to create a replica of Wayang Beber of Pacitan paintings. Now the replica is kept in the Radyapustaka Museum at Surakarta City, Indonesia. Today Wayang Museum in Jakarta also has another replica of Wayang Beber of Pacitan paintings. It was made by Musyafik, a staff at East Java Regional Office of Departments of Education and Culture of Republic of Indonesia.

Preservation efforts have also been commenced by communities and academics. Lis [10] mentioned the existence of two artist communities in Surakarta, namely Wayang Beber Kota and Wayang Beber Welingan. Both communities have tried experimenting with Wayang Beber and presented it in a contemporary form. Similar attempt has also been done by Wayang Beber Metropolitan community in Jakarta, Indonesia. They often perform a new creation of Wayang Beber bringing up some social issues. In the academic field, preserving Wayang art has become a concern in researches such as those conducted by Aulian et al. [11] and Trihanondo et al. [12]. In those researches, the preservations are performed using new media. Aulian tried utilizing mobile device for introducing Wayang Kulit of Cirebon, while Trihanondo offered an adaptation for Wayang Golek puppets into game characters. Both researches made an effort to acquaint young generation of users with Wayang. However, particularly for Wayang Beber of Pacitan such an approach has never been done.

1.1.4 Challenges for Wayang Beber of Pacitan Preservation

In this thesis, several challenges in the preservation of Wayang Beber of Pacitan have been identified. Those are:

1. Limited access to Wayang Beber of Pacitan

   Until now, Wayang Beber of Pacitan is kept privately by the official storyteller in Pacitan town. It is difficult to be accessed by public. Since it is considered as a sacred object, it should be shown and performed only in special occasions.

2. Humid climate of Indonesia

   In a humid climate, it is difficult to keep the paintings in a good condition. Humid climate not only gives bad effects for papers, but also encourages molds to grow on the paintings.

3. Characteristics of Wayang Beber of Pacitan as a theater art.

As a theater art, Wayang Beber of Pacitan is performed to deliver a story. The story is an important aspect of Wayang Beber of Pacitan. It contains local wisdoms and knowledge that have been passed down from generation to generation. Wayang Beber of Pacitan story and performance cannot be preserved only by using replication of its paintings.

4. Decrease number of Wayang Beber artists and storytellers

The last traditional Wayang Beber was made around the 17th century. Since then, a new type of Wayang Beber was never made. At the present, only a few self-taught artists dedicate themselves to make replicas of Wayang Beber paintings. Most of these artists are old in age. They are the only source from whom to study the making of Wayang Beber of Pacitan painting.

Another problem is the lack number of Wayang Beber storytellers. Wayang Beber is a performance art that should be performed by trained storytellers. In the past, only a chosen man could become a Wayang Beber storyteller. He should be chosen and taught by the previous storyteller in order to become a successor of the storyteller. Today, officially there are only two Wayang Beber storytellers, one being storyteller of Wayang Beber of Pacitan and the other the storyteller of Wayang Beber of Wonosari. Because of this reason, Wayang Beber performance is difficult to be found.

5. Limitation of Wayang Beber of Pacitan as a narrative medium

Tabrani [13] inferred that the declining of Wayang Beber of Pacitan art is also caused by the limitation of its medium. Wayang Beber of Pacitan is static narrative media. In its performance, people only see sequences of still pictures narrated by the storyteller. It was popular before 15th century in Java. The emergence of more advanced Wayang types that have more dynamic performance made people start to leave Wayang Beber behind. Today only a few people have interest to study Wayang Beber art.

Based on these challenges, the problems for preservation effort can be elaborated. Those problems are:

1. How to open the access of Wayang Beber of Pacitan to wider public?
2. How to create preservation medium that can sustain in a humid climate?
3. How to create medium that can be used to preserve Wayang Beber Pacitan story and performance?
4. How to perform the story of Wayang Beber of Pacitan without the presence of storyteller?

5. How to increase the public interest in Wayang Beber of Pacitan?

1.1.5 Incorporating 3DCG Animation for Preserving Wayang Beber of Pacitan

In this thesis, 3DCG animation is proposed as a medium for preserving Wayang Beber of Pacitan. There are several reasons for using 3DCG animation:

1. 3DCG technology is able to digitalize Wayang Beber of Pacitan painting.

   Theater art, such as Wayang Beber of Pacitan, is classified as an intangible cultural heritage. UNESCO defines the intangible cultural heritage as the practices, representations, expressions, as well as the knowledge and skills that communities, groups, and individuals recognize as part of their cultural heritage [14]. The purpose of preservation of an intangible cultural heritage is not only to keep the physical form of the heritage, but also to transmit the knowledge and skill that are embodied in the heritage to the next generation. There is a possibility that an original artefact of a heritage will be lost in the future, but if the knowledge and skill are preserved, the artefact can be re-created. For this reason, a digital archive and documentation are important for the intangible cultural heritage preservation.

   3DCG can be used to document or simulate a heritage and store it as a digital archive. So that, in the future, the knowledge and skills related to the heritage can be studied from this digital archive. Digitalization makes the archive more durable. It is also easy to be disseminated.

2. 3DCG animation can be used as narrative media to tell story.

   As mentioned before, the preservation of Wayang Beber of Pacitan has already begun with the replication of its paintings, yet replicas of the paintings are not enough to preserve Wayang Beber of Pacitan. Without performances, the story of Wayang Beber of Pacitan will be lost. Using 3DCG animation, the story can be preserved. It can be delivered without the presence of storyteller.

3. New possibilities of the non-photorealistic 3DCG.
   The introduction of the non-photorealistic CG concept in 1994 opens new possibilities in a CG production. Since the beginning, CG productions have been dedicated to produce images which resemble a photograph by simulating physical processes of photography. Non-photorealistic CG seeks for another purpose. It tries to produce images that resemble human-drawn pictures [16]. Researches on non-photorealistic CG are dedicated to simulate artistic media and style. This technique can be used to simulate visual style of Wayang Beber of Pacitan in CG

animation.

Non-photorealistic rendering technique makes 3DCG animation more proper to be used as media for supporting Wayang Beber of Pacitan preservation. It can be used to preserve the story as well as to simulate the visual style of Wayang Beber of Pacitan paintings. The visual style is an important aspect in this preservation effort. As stated by Engel [15] without incorporating a relevant traditional visual style, many traditional Asian stories lose artistic connection with the story's roots and relevance when it is translated into an animation. This problem occurs in many 3DCG animations from South East Asian countries. According to Rall [16], although those animations tell a traditional story, the style of American caricatured-realism is still chosen as preferable artistic style to ensure a commercial success. This style is used in various 3DCG animations made by Disney and Pixar studios. The style can be described as a caricatured figure depiction that is rendered with photorealistic technique.

4. The efficiency of 3DCG animation system production.

3DCG system has a digital skeleton feature that is very useful for animating a character. Using this feature, an animator only needs to pose the skeleton in several key frames, and then the software will automatically interpolate the in-between frames. The digital skeleton in 3DCG system is convenient and can be controlled easily.

In contrast, in 2DCG system there are two methods for animating a character: animating frame by frame and using key frames. Animating a character frame by frame creates a more accurate movement than using the key frames. However it is difficult and takes a long production time. Animating character using key frames is more convenient. However, compared to 3DCG production it has disadvantages. Although 2DCG system also has a skeleton feature, its movement is limited, and it is more difficult to be controlled. Sometimes, the skeleton distorts the character's figure. If this problem occurs, it needs more time to be fixed.

3DCG programs used in this research such as Autodesk MAYA, and Pixar Renderman, also provide many programmable functions. They can be used to develop a specific program that is useful for creating Wayang Beber animation. In this research, a specific program is created to make a customable outline and pattern. Using this program, artists can create outlines and various patterns that they need for the animation production.

The 3DCG animation has advantages to be used as a media for supporting Wayang Beber of Pacitan preservation. In this thesis, non-photorealistic rendering techniques are applied to develop the animation. Nevertheless, non-photorealistic rendering is a broad term. Specific techniques are needed to meet this purpose. The required techniques can be known by following a procedure proposed by Curtis [17]. The procedure begins with stating a visual goal for the rendering. Visual goal is a clear mental image of what the finished product should look like, it must be able to describe the tiniest detail of desired image. This goal then should be clearly specified as an art direction. The art direction will determine the techniques which should be applied or developed in order to meet the goals.

In this thesis, the visual goal is obtained by analyzing Wayang Beber of Pacitan visual style. The complete report from the analysis can be read in chapter III of this thesis. It is concluded that there are two required techniques: outline rendering, and pattern generation. Furthermore, rendering is just one stage of CG animation production. The animation process itself has its own problems. Similar to Chan and Chen's project [18], this research intends to add the third dimension to a two-dimensional painting by using a computer technology. The painting has traditionally been restricted to two dimensions which do not have a movement. To animate a Wayang figure, a new movement design and certain key poses are needed. Based on these requirements, there are three technical issues which are examined in this thesis; those are outline rendering, pattern generation, and key pose extraction from Wayang Beber of Pacitan painting.

1.2 Review on Wayang Beber of Pacitan Art

There is limited information about techniques or procedure to create Wayang Beber of Pacitan painting. Research on Wayang Beber of Pacitan from the perspective of visual art is surely needed. However, only few researches have been conducted. Two notable researches were conducted by Tabrani [19] and Salim [20].

Tabrani analyzed Wayang Beber of Pacitan painting as a visual language. He proposed a theory explaining that the visual composition in Wayang Beber of Pacitan painting has certain grammar that is useful to convey a story. This grammar is included in a system which he called as a Space Time Plane (STP) system. STP system is defined as a depiction of different spaces and times within one single image. This system allows the image to represent a movement or sequence of stories.

There are two important concepts in the theory of visual language described as the

image and the grammar. The image always consists of two parts, the content of the image and the method to draw the image. The content of the image is an object that is represented by the image. The method to draw gives certain meanings to an image. For instance, when an image is drawn bigger than the other, it means that image is important. Sometimes some images are drawn distorted. It probably means that they are moving.

Grammar is a set of rules to compose and read images. There are two types of grammars; the inner grammar and the outer grammar. The inner grammar is used to compose images in a single picture, while the outer grammar is used in sequential pictures. Wayang Beber of Pacitan has sequences of pictures, so that it has both the inner and the outer grammars.

The theory of visual language helps to understand the meanings of Wayang Beber of Pacitan painting, and clarifies the relation between the visual and its story. However, this theory does not explain much about Wayang Beber of Pacitan visual style.

Another researcher named Salim did a study on the appearance of Wayang Beber of Pacitan paintings. He examined color, shape, and composition of the paintings. His study is based on the notion that Wayang Beber of Pacitan is made using a Javanese traditional painting technique called *sungging*. This technique is still widely used by traditional artisans to paint the puppets of Wayang Kulit Purwa. The procedures of the *sungging* technique in a production of Wayang Kulit Purwa were thoroughly discussed by Ahmadi [21], and Purbasari [22], and Sukir [23]. The procedures are strict. They have to be followed thoroughly by the artisans. The result of *sungging* technique is easily recognized since it produces a particular color composition and pattern. Each color composition and pattern has a specific name such as *tlacapan, byor, cawi, bludiran, drenjeman, ulat-ulatan*, and *sembuliyan*. Salim's research tried to identify this particular color and pattern in Wayang Beber of Pacitan painting.

1.3 Review on Digital Preservation of Cultural Heritage

As mentioned by Rahaman [24], heritage refers to the study of human activity not only through the recovery of remains but also through tradition, art and cultural evidences and narratives. Smith [25] describes heritage as a process of engagement rather than a condition. As explained further by Graham [26], heritage is a medium of communication, a means of transmission of ideas, values, and knowledge. It includes the material, the intangible and the virtual object.

Now, there is a new approach to preserve a heritage. It uses digital heritage. Digital heritage is defined by UNESCO [27] as unique resources of human knowledge and expression which are created digitally or converted into a digital form from the existing analogue resources. Based on this definition a 3DCG animation simulating visual style of Wayang Beber of Pacitan could be categorized as a digital heritage.

Rahaman [24] stated three stages of digital heritage production: documentation, representation, and dissemination. Documentation consists of cultural values or knowledge from both tangible and intangible heritage. Representation is a digital content of such text, image, moving picture or digital virtual environments that possess the values. Dissemination is a process of transmitting digital contents to end users that involve media either in the form of hardware, software, or narrative. Researches on digital heritage deal with either two or three of these stages.

As an example, a research conducted by Azi [28], examined the practice of Afrimation (African Animation) in promoting African cultural heritages. This research focused on analyzing the impact of African animation for promoting African heritages, and proposed certain policy to optimize its extent. Another research by Duruaku [29] accessed a possibility of using animated film to revitalize Igbo Heritage in Africa. This research brings out several recommendations for animation production regarding the method to deliver a traditional content and to approach a young generation of viewers.

Another approach is taken by Ghani [30]. He conducted a study of digital puppetry and computer graphic techniques to visualize Wayang Kulit of Kelantan. Such approach was also performed by Miyazaki et al. [31] who studied a technique to create a digital model of the Buddha statue as a heritage in Kamakura, Japan.

The first approach such as performed by Azi and Duruaku examines the representation and dissemination stages of digital heritage production. They tried to assess interaction between users and the digital contents. They measured effectiveness of the digital contents as a tool to convey values and knowledge to the users. These types of study intend to understand the interaction from the perspective of the users. The second approach used by Ghani and Miyazaki examines the documentation and representation stages of digital heritage production. They tried to examine technical feasibility to represent cultural values in digital media.

1.4 Review on Non-photorealistic CG production

1.4.1 Silhouette Rendering

Silhouette rendering is performed to obtain an outline or contour line of 3D model

in the rendered images. Silhouette rendering algorithm deals with two main problems: detection of silhouette edges, and determining the visibility subset of the silhouette edges. Gooch et al. [32] defined silhouette as the point on the surface where dot product between viewing direction vector and surface normal is equal to zero (0), or the angle between viewing direction vector and surface normal is 90 degrees (see Figure 3).

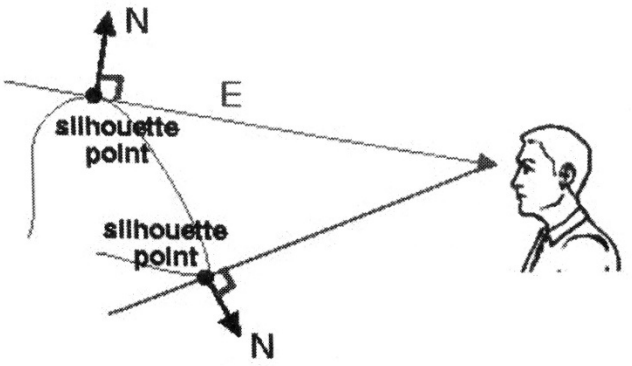


Figure 3. Gooch's definition of a silhouette[3] [32]

Isenberg et al. [33] classified the silhouette rendering algorithm as follows:

1. Image-based algorithm where silhouette is represented in an image buffer.
2. Object-based algorithm where silhouette is represented by description of silhouette edges of 3D objects.
3. Hybrid algorithm which combines the two previous algorithms.

Early application of image-based algorithm is proposed by Saito and Takahashi [34]. Their research provides data structure and algorithm that are required for drawing discontinuities, edges, contour lines, and curves hatching from image buffer. The advantages of this approach are algorithmic stability and independency from model surface representation. However the computed silhouette edge is not too accurate. Another research using image-based algorithm is done by Curtis [35]. He offered a method which uses image processing and a physical based particle system. As a result, stylized silhouette edges could be achieved. This method can be applied to create variety of line styles. However, it may not get all silhouettes and creases since it is computed based on the content of image buffer. In general, image-based algorithm is fast; nevertheless its result is less precise.

In object-based algorithm, the simplest method is to test every edge in the model. A silhouette can only appear on an edge that is shared by front facing polygon and

[3] ©Gooch, A K Peters

back facing polygon. However this method is inefficient, especially if it is applied in a large model. As an alternative, another method is proposed by Buchanan and Sousa [36]. They used edge buffer data structure to speed up the calculation of silhouette edge detection. In this data structure, they put additional data for each edge which corresponds to a front facing (F) or back facing (B) flag. When the polygon is rendered, each polygon is tested whether they are front or back facing. The F and B field in edge buffer array is XOR by 1. XOR or "exclusive or" (exclusive disjunction) is a logical operation that the outputs true if both inputs are differ. As a result, if an edge is adjacent to a front facing and a back facing polygon, the F and B bits are 11. This method has disadvantage because it requires big memory and a long time to be performed since all polygons are calculated during rendering process. Another method is performed by Benichou [37], by applying projection face normal onto Gaussian sphere. Every edge of the mesh corresponds to the arc of the Gaussian sphere which connects the normal projection of its two adjacent polygons. In orthographic projection, the view of the scene is equal to a plane which is through the origin of the sphere. Every arc which is intersected by this plane is a silhouette edge. Using this approach, there is no need to check each frame if every face is front facing or back facing. Similar method is also developed by Gooch et al. [38]. Herztmann and Zorin [39] proposed a different method; they used a data structure based on dual representation. This method creates dual representation of mesh in 4D space build upon position and tangent plane of each vertex. To find a silhouette, this method uses the inverse: each plane in dual space corresponds to a point in the original 3D space. Object-based silhouette rendering is more accurate however; it usually needs more time to perform.

The third method is called hybrid algorithm. It combines image-based and object-based algorithm to increase efficiency. Example of this method is a work by Raskar and Cohen [40] in which they used a depth buffer to find a silhouette. The front and back facing face is rendered separately, the silhouette displayed by computing intersection of adjacent front facing and back facing layer in the image space (see Figure 4). The hybrid approach can also be used in silhouette artistic rendering. This method was developed by Martin and Torres [41]. Using this method, they generated a virtual light which allows users to specify appearance of silhouette on the object.

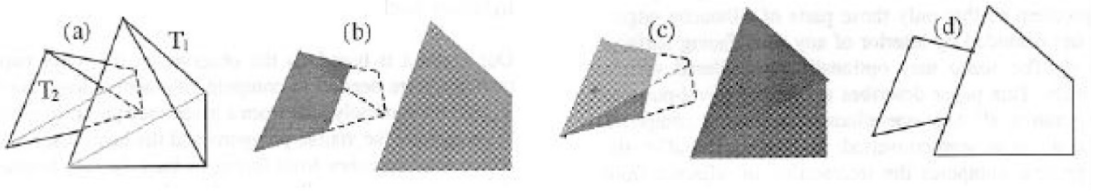


Figure 4. Raskar and Cohen's method. **The first layer, *PI,* for scene (a) is made up of the parts of nearest front facing polygons (b), The second layer, *P2,* is made up of parts of back facing polygons (c). The interesection of these two layers in image space creates silhouette edges (d)[4] [40].**

1.4.2 Art Pattern Generation

Art pattern can be defined as a repeating unit of shapes in an artwork. To get a better understanding of the art pattern generation, this chapter begins with a discussion about art pattern components. According to Lu et al. [42], there are four basic components, those are: graphic entities, layout, colors, and textures. Graphical entities are considered as sub-art patterns. They contain a composition of geometric primitives such as points, lines, and faces. To create an art pattern, multiple graphical entities are arranged.

The second component is lay out. It is spatial relationships between graphical entities in an art pattern. The third component is colors. Basically viewers' perception of an art pattern is determined by colors. All shapes as a foreground or background object in art pattern can be distinguished by viewer because of color differences. The last component is the textures. It is a high level graphical primitive which has a highly coupled structure inside. The textures can be the background of art pattern or a special effect for the graphical entities.

As stated by Geng [43], there are four methods of pattern creation: art pattern creation by fractal, art pattern creation by shape grammars, layout based art pattern, and knowledge based art pattern. Currently, the first method is proposed as a new approach in Indonesian batik pattern creation such as performed in works by Hariadi [44] and Yulianto [45]. Batik is an Indonesian traditional art technique for creating pattern on textiles. Fractal such as used in Hariadi or Yulianto's work offers a novel aesthetic style in Batik art.

The second method, the shape grammars, was proposed by Stiny [46]. He defined shape as a limited arrangement of straight lines in a Cartesian coordinate system with real axes and an associated Euclidian Metrics. The shape grammar method creates an art pattern by applying a set of rules to arrange a shape or shape formation. According to Tapia [47] this approach consists of three major phases,

[4] ©Raskar and Cohen

namely: creating and modifying shape grammar, compiling the grammar, exploring the resulting art patterns defined by the grammar.

Third method is called layout-based pattern creation. Geng [43] summarized several approaches in this method, as follows: layout creation based on regular structures, layout creation integrated with the fabrication process, and an art pattern creation by stylized layout. The first approach which is based on regular structures is simple and convenient; however, the generated pattern has seems artificial. The second approach is integrated with fabrication of craft. It is able to create suppler and artistic shape; nevertheless it is still restricted on a regular layout structures. The third approach is stylized layout approach. Using this approach, users can use specific graphical entities such as texts or image to fill the layout. An xxample of this method is performed by Kaplan and Salesin [48] to create simulation of "Escherization".

1.4.3 Evaluation of Non-Photorealistic Rendering

Geng [49] describes that photorealistic CG basically is used to imitate the eyes and mind of an artist or designer to view and create a graphical world. Based on this purpose, there are core problems in non-photorealistic CG:

1. How to create an art from a blank canvas.
2. How to convert source of images into pictures with a desirable visual effect.
3. How to generate artistic rendition from 3D.
4. How to synthesize expressive pictures from textual, graphical or pictorial data.
5. How to accelerate the production of cartoon animation sequences with temporal coherence.

These core problems show that Non-photorealistic CG mainly deals with a subjective matter such as aesthetic and artistic sense; therefore, as stated by Gooch [50] and Salesin [51], its result is difficult to be evaluated. Nevertheless, various evaluation methods have been developed.

Isenberg [52] describes that in general the evaluation process could be classified into two categories:

a. Qualitative evaluation, which tries to gain a richer understanding of the subject matter by taking a more holistic approach. It uses techniques like observation and interviewing
b. Quantitative evaluation, which focuses on hypotheses, measurable variables in controlled experiments, and a statistical analysis of the results

For Isenberg both evaluations are reliable, depending on the motivation of the non-photorealistic rendering that is performed. Thus, the first important thing is to specify the goal of the project itself. It will determine how to perform the evaluation.

A plausible evaluation approach is proposed by Herztman [53]. He infers that evaluation of non-photorealistic rendering can apply the same procedure used to evaluate human aesthetics. The approach can be qualitative or quantitative. For a given non-photorealistic rendering algorithm or formula, Herztman derived a set of rules of images that should be produced. These rules are designed so that one can judge whether or not an existing artwork satisfies them. It should be specified using a simple sentence that can be understood without advanced technical knowledge, for example, "leg strokes should be thicker than arm strokes". Then, one can assess to what degree these rules are obeyed by the existing artworks. The assessment can be done by the researcher or using a user study.

Similar approach is offered by Mould [54]. However Mould believes that the evaluation is better to be done by the researcher himself. He argues that a user study cannot substitute an expert judgment.

Mould offers a qualitative method called authorial subjective evaluation. He suggested a structured qualitative analysis of images. A rendering result is described using initial object as a reference. Mould suggested four stages for evaluation:

1. Compile a list of the characteristics of interest.
2. Identify the most important features and justify the assessment.
3. Show varied examples of the results.
4. Evaluate the examples according to their adherence to the important features mentioned.

Other evaluation methods are performed by using user studies. Salesin [51] performed series of test to evaluate non-photorealistic rendering. He showed two images to users. One is a non-photorealistic 3DCG rendered image and the other one is an image made by hand. For the evaluation, Salesin asked the users whether they could distinguish those two images.

Another user study is performed by Cole [55]. Cole asked a group of users to make a drawing. Then those drawings are used to evaluate a non-photorealistic 3CG image. Cole compared the attributes of the drawings to the attributes of the 3DCG image.

A different approach of user study is proposed by Wyvil et al. [56]. In the study, users are asked to compare non-photorealistic 3DCG images. Then they should give a score for each image according its aesthetic value by using a Likert scale. Likert scale is a method that is commonly used to measure attitude, providing a range of responses to a given question or statement [57]. Typically, there are 5 categories of response, from strongly disagree which is equal to 1 point to strongly agree which is equal to 5 points. By using an average score from this scale, non-photorealistic 3DCG can be evaluated.

Evaluations in this thesis are performed using two methods. The proposed methods for rendering Wayang Beber of Pacitan outline and generating the pattern are evaluated using authorial subjective evaluation method such as proposed by Mould [54] and Hertzman [53]. The proposed animation procedure is evaluated using a user study such as proposed by Wyvil et al. [56].

1.5 Scope of Thesis

This thesis mainly focuses to develop methods for creating 3DCG animation based on Wayang Beber of Pacitan painting. The animation will be used as supporting media for preserving Wayang Beber of Pacitan story and performance.

This thesis is a combination of technical and art content researches. 75% of the contents of this thesis are technical researches and 25 % are art content researches. These two types of research cannot be separated. The art content researches are an important foundation for the technical researches. They determine the goals and parameters to evaluate the result of the technical researches (See Figure 5).

The art content researches are performed to gather comprehensive documentation regarding the visual style of Wayang Beber of Pacitan, particularly related to its character figures. In this research, information is obtained from interviews, literature study, as well as comparative study between Wayang Beber of Pacitan and the others types of Wayang. The purpose of this research is not only to find description of visual features and painting technique, but also to understand historical and philosophical aspects of the visual style of Wayang Beber of Pacitan.

The technical researches examine technical issues to build a digital representation of Wayang Beber of Pacitan in 3DCG. There are three issues to be solved. Those are outline rendering, pattern generation, and key pose extraction.

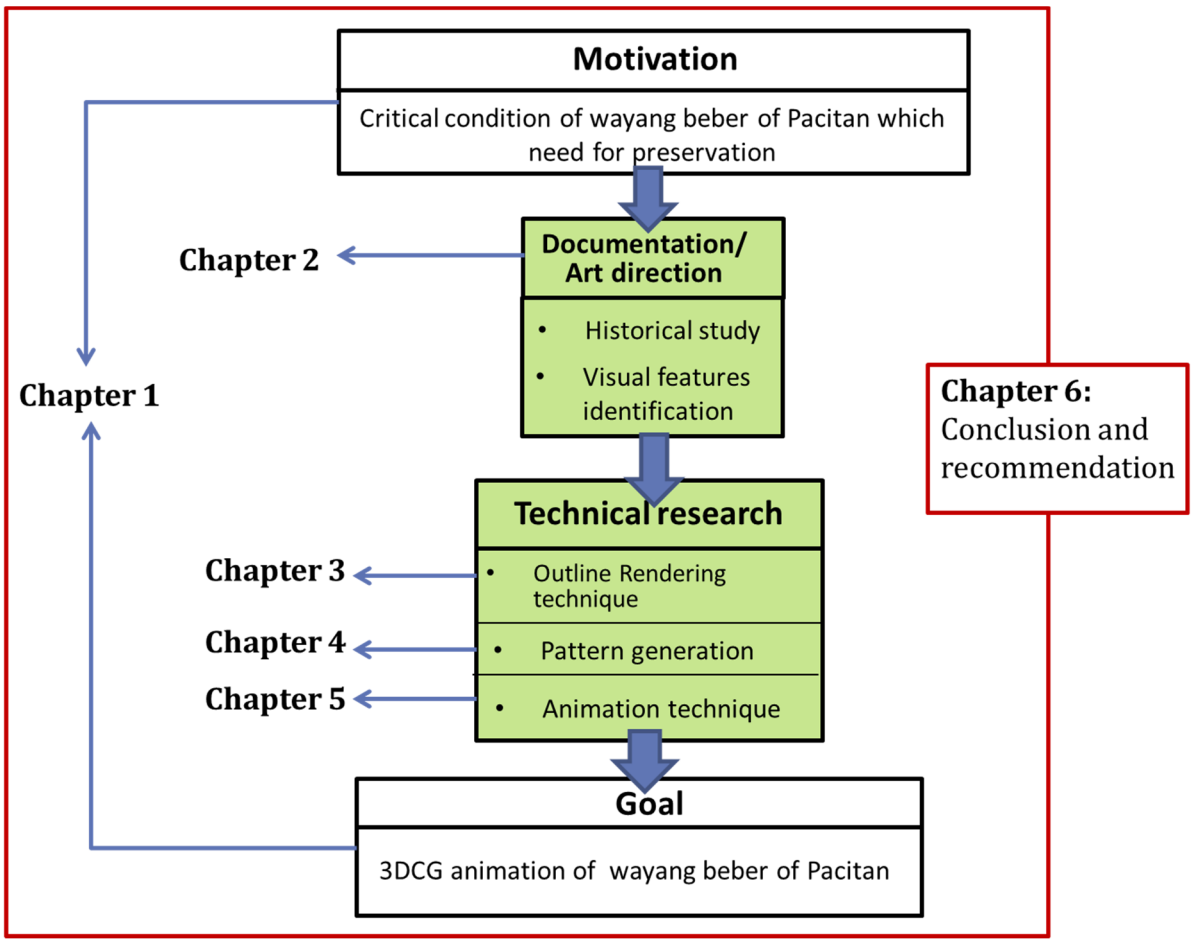


Figure 5. Research Scheme

1.6 Research Objectives

This thesis mainly aims at helping preservation of Wayang Beber of Pacitan by using 3DCG animation. For this attempt there are three specific goals:

1. Build a comprehensive documentation regarding the visual style of Wayang Beber of Pacitan. This documentation contains several aspects related to Wayang Beber of Pacitan painting, such as:

   - A Guidance to design the character figures,
   - A Procedure to make the painting,
   - The art philosophy of Wayang Beber of Pacitan.

   This documentation is devoted not only for production of CG animation in this project, but also to provide data for future research on the Wayang art.

2. Develop the required techniques for translating the painting into 3DCG animation, such as:

- A technique for simulating an outline of Wayang Beber of Pacitan character figures in 3DCG
- A technique for simulating pattern of Wayang Beber of Pacitan in 3DCG
- A key poses extraction to create an animation from Wayang Beber of Pacitan painting.

3. Assess feasibility of simulating Wayang Beber of Pacitan visual style in 3DCG.

Evaluations of each of the developed techniques is expected to give a comprehension on how far the traditional visual art of Wayang can be applied in 3DCG animation. This will give benefits for development of an alternative aesthetic approach in Indonesian 3DCG animation in the future.

1.4 Layout of Thesis

This thesis is divided into 6 chapters as follows:

Chapter 1 describes background, scope, and objectives of the research. This chapter also provides review of related researches in Wayang Beber of Pacitan art, digital preservation of cultural heritage, and specific non-photorealistic CG techniques such as: silhouette rendering, pattern generation, and non-photorealistic rendering evaluation.

Chapter 2 discusses identification of the character figures visual style in Wayang Beber of Pacitan. The origin of the visual style and its transformation are explained. The visual style of the character figures is analyzed to understand its typical visual features. This chapter is fundamental for this thesis, as it is used as a visual goal for each study in the next chapters.

Chapter 3 discusses the development of shader for rendering an outline of Wayang Beber of Pacitan figure in 3DCG. This chapter is divided into two discussions. In the first discussion, features of the outline of Wayang Beber of Pacitan figure are described. The second discussion talks about the development of outline shader.

Chapter 4 discusses development of procedural patterns for simulating Wayang Beber of Pacitan art pattern. This chapter is divided into two discussions. The first discussion describes the typical art pattern found in Wayang Beber of Pacitan. The second discussion of this chapter explains the development process of the procedural patterns. Several experiments are conducted by applying various variables to the program. The result is examined to get the desirable pattern.

Chapter 5 contains two discussions. The first discussion explains a procedure to extract key poses from Wayang Beber of Pacitan painting. The result of the

extraction is described and evaluated. The second discussion explains about a process to elaborate principles of the movement of Wayang characters. Then the principles are applied to interpolate in-between frames for animating the character.

Chapter 6 contains compilation of all concluding remarks from chapter 2 to chapter 6, and also gives over all conclusion of the researches to develop methods for creating a Wayang Beber of Pacitan 3DCG animation.

Chapter 2.
Identification of the Character Figures' Visual Style in Wayang Beber of Pacitan Painting

2.1 Overview

This chapter discusses the origin Wayang Beber of Pacitan figures' visual style and identification of its features. The visual style of Wayang Beber of Pacitan can be seen as one of the Javanese artistic tradition pinnacles. A research by Nuning Adisasmito [58] found that the visual style of Wayang Beber has a strong influence for Javanese illustration in 19th century. It also inspires some Indonesian visual artists today, such as Wayang Beber Metropolitan Community in Jakarta, and an artist named Dani Iswardana from Surakarta, Indonesia.

Visual style in this chapter is defined as a distinguishable ensemble of visual characteristics, qualities, or expression in the work of art [59].

This chapter consists of two parts. In the first part, the origin of the visual style of Wayang Beber of Pacitan figure is traced. In the second part, distinguishable features of the visual style are analyzed.

2.2 Origin and Transformation of Wayang Beber of Pacitan figure Visual Style

2.2.1 Brief History of Indonesia

In general, history of Wayang art is related to the existence of the ancient Kingdoms in Indonesia. Thus, it is better to understand the brief history of these ancient Kingdoms in Indonesia.

The Republic of Indonesia proclaimed its independence in 1945 AD; nevertheless the name of Indonesia was formally introduced in 1928 AD. Previously, this name was often used to identify the Dutch colony in Southeast Asia region. The colony included a vast archipelago which lies between Southeast Asia (Malay) Peninsula and Australia Continent. Before Dutch colonialism, historians often divided the history of this archipelago into three periods, it began with the pre-historic period, then Hindu-Buddha period, and the last is Islamic period.

During these periods, there existed many of kingdoms and the kingdoms reigned one after another. Several of them which are mentioned in this thesis existed in Java Island. The first is Kediri Kingdom; it existed in the 12th century during Hindu-Buddha period in Central Java [60]. The second is Majapahit Kingdom. It was founded in 1293 AD [61]. Majapahit Kingdom was the last Hindu Kingdom in Central Java. It fell down around 1478 AD, and was succeeded by Demak Kingdom. The rise of Demak Kingdom signified the beginning of Islamic period in Java. The last kingdom which is mentioned in this thesis is Islamic Mataram Kingdom; it was established around 1590 AD and collapsed in 1755 AD [62]. Wayang arts were developed during the reign of these ancient Kingdoms. It was made at the behest of the kings.

2.2.2 Origin of Wayang Beber of Pacitan Figure Visual Style

A popular argument said that Wayang Beber of Pacitan came from the era of Majapahit Kingdom during Hindu period in Java. It is told that the paintings were given by the Majapahit King to the first storyteller named Naladerma as a gift for curing the Majapahit Princess. Information such as written in a record made by Ma Huan, a Chinese voyager who visited Java in 1416 AD [63], also infers that Wayang Beber has existed since the era of Majapahit Kingdom. Ma Huan stated that he saw a Wayang Beber performance performed in a ritual. He did not give any explanation regarding the story and the visual of Wayang Beber that he saw at that time. This

information is supported by Mulyono [64]. He mentions that there was a Wayang Beber which was made in 1361 AD. However he presumes that Wayang Beber is Wayang Beber Purwa. This argument is also supported by Sarman [65], and Mataram [66]. The word *purwa* means first or beginning English. In Wayang, the word *purwa* also refers to a story from ancient Javanese literature which is derived from a Hindu story of Mahabharata, Ramayana, and Purana [67]. So Wayang Beber Purwa is a Wayang Beber that tells a story which is derived from Hindu mythology. Therefore Wayang Beber that was made in 1361 is not Wayang Beber of Pacitan.

Based on its story, Wayang Beber of Pacitan can be categorized as Wayang Panji. Wayang Panji tells a Panji story. According to Sumaryono [68] Panji story originated in Java, it tells chronicles of the dynasties in ancient Kingdoms of Java such as Jenggala, Urawan, Kediri, and Singasari which existed before Majapahit era. Sumaryono also explains that Panji story was popular in Java in 1375 AD during Majapahit era. This information shows that it is also plausible that there was Wayang Beber which told Panji story in Majapahit era.

Another researcher named Sudarajat [69] mentioned about the existence of another Wayang Beber type in Majapahit era. He states that in 1378 AD, Majapahit King named Brawijaya ordered his son to paint a set of Wayang Beber paintings. The paintings were colorful and painted on paper scrolls. Its visual style was referred to the figure on Wayang Batu of Panataran. Wayang Batu is a Wayang carved on the stones which can be found on reliefs of Hindu temple of Panataran in East Java (see Figure 6). It was made in the 11th century.

Nevertheless, another researcher named Tabrani [13] contends that Wayang Beber which existed in Majapahit era is not Wayang Beber that we know as Wayang Beber of Pacitan today. According to Tabrani, it seems unlikely that the visual style of Wayang Beber of Pacitan painting came from the Majapahit era in Hindu period. He referred to Sayid, a Wayang performer and expert, who described that style of Wayang figure that came from Hindu period, had more realistic depiction.

The example of Hindu style depiction can be observed in other types of Wayang such as Wayang Batu of Panataran temple or Wayang Kulit of Bali. Wayang Kulit of Bali is Wayang made of leather that can be found in Bali Island (see Figure 7). Until now Bali has a strong Hindu tradition. In contrast to Java, Bali has never been strongly influenced by Islam. Therefore Wayang Kulit of Bali has not changed as opposed to what happened to Wayang in Java.

The figures in Wayang Batu of Panataran and Wayang Kulit of Bali have the same

typical features. In general, the figures seem to be depicted from the side. Although the shape has been stylized and simplified, their proportions still resemble a human figure. The figures are not as thin as those of the figures of Wayang Beber of Pacitan.

The figures of Wayang Beber of Pacitan have more similarities to the Wayang that came from the Islamic period. A paper written by Koesoemadinata explains that the Islamic style of Wayang figures began to be used in Wayang Kulit Purwa (see Figure 8). It signified the transition from Hindu period to Islamic period in Java [7]. The Islamic era in Java began after the fall of Majapahit kingdom around 1500 AD. The style was a result of the inclusion of Islamic values into the Wayang art. The differences between Hindu style and Islamic style of depiction in Wayang can be seen in table 1. Based on this finding, it can be concluded that Wayang Beber of Pacitan is not the Wayang Beber Panji that was made in Majapahit era. In the past, Wayang was made under patronage of the reigning monarch; therefore it seems unlikely that Wayang figures that were influenced by Islamic values were made under Hindu patronage.

Figure 6. Relief on Panataran Temple[5] [70]

[5] © Kinsbergen, tropenmuseum

Figure 7. Wayang Kulit Bali[6] [71]

Figure 8. Wayang Kulit Purwa Puppet[7] [72]

Table 1. The differences of Hindu style and Islamic style of depiction in Wayang

Hindu Style	Islamic Style
• Less stylized • Head, neck, arms, and legs of the figure are not distorted • The figure's body is not too thin • Resemble to real human • Does not incorporate iconographic symbolization.	• More stylized • Head, neck, shoulders, arms, and leg are distorted • Generally, the figure's body is thin • Avoids a resemblance to real human • Incorporates iconographic symbolization

6 © Wayang Museum, Jakarta, Indonesia

7 ©Tropenmuseum

Presently, the traditional Wayang Beber that has Hindu style depiction cannot be found anymore in Java. According to Tabrani [13] and Mulyono [63], when Demak, the first Islamic Kingdom in Java conquered Majapahit, all relics including Wayang Beber Purwa were taken. The possession of the relics was seen as a symbol of domination. Then, the king and religious leaders of Demak created a new type of Wayang called Wayang Kulit and used it as a tool for spreading Islam [73].

Wayang Beber taken from Majapahit was used as a reference for that new type of Wayang. Modification was done to its story and the figure style to follow the Islamic rules. There was an interpretation of Islamic rules at that time that forbid a realistic depiction of human figure [74]. A figure depiction such as found in temple relief was left; Wayang figure was more stylized and made using symbolism [75]. The figure was more simplified and was depicted from the side. Instead of painted on a piece of paper, Wayang figures were separated one by one. The figure was made into a flat puppet using leather. Then this type of Wayang was known as Wayang Kulit Purwa (see Figure 8). Wayang Kulit Purwa kept on improving; the form of Wayang Kulit Purwa that is known today appeared around year 1613-1645 AD in the era of Islamic Kingdom of Mataram [76]. In 1693 AD, Wayang Kulit told a Panji story was made. It is known as Wayang Kulit Gedog.

As explained by Mataram [66] and Susanto [77] , after Wayang Kulit Purwa was made, officially, Wayang Beber was forbidden to be performed inside the palace; however Wayang Beber was still performed by the people outside the palace. As mentioned by Mulyono [78], in 1564 AD, a new Wayang Beber Panji was also created. However Mulyono does not explain in more details about this type of Wayang Beber.

So, at that time there were two different types of Wayang performance, Wayang Kulit, and Wayang Beber, wherein each of the performance had different purpose. The official performance of Wayang Kulit in the palace was performed to teach Islam, whereas the people outside the palace often invited a storyteller to perform Wayang Beber Purwa in some ritual to pray for their health, safety, and prosperity. This matter became a concern for the religious leaders at that time. The Wayang Beber performance outside the palace was seen as diversion of Islamic teaching. According to Susanto, since Wayang Beber Purwa was still popular for the people at that time, as a solution a new type of Wayang Beber that was appropriate to Islamic rules was created. The new Wayang Beber told a Panji story. Based on Salim [20] and Tabrani's [13] argument, it can be inferred that this new type of Wayang Beber is Wayang Beber of Pacitan. Tabrani and Salim believe that Wayang Beber of Pacitan was made

after Wayang Kulit Purwa. They infer that the figures in Wayang Beber of Pacitan were made by following the style which is used in Wayang Kulit Purwa and Wayang Kulit Panji (see Figure 9).

Figure 9. Wayang Beber of Pacitan Figures

Researches done by Sudrajat [69] and Sayid [79] explain a method to find out the production year of the Wayang Beber of Pacitan painting. A traditional Wayang artefact has certain pictures symbolizing the production year. To read the symbol, one should understand the Javanese philosophy properly. As explained by Sudrajat the symbol in Wayang Beber of Pacitan painting could be interpreted as 1614 (Javanese year) or 1692 AD. The symbol supports the argument that Wayang Beber of Pacitan was made after Wayang Kulit Purwa. It was created approximately in 1692 AD within Islamic Kingdom of Mataram era at Kartasura city in Central Java. Then in 1742 AD, there was a rebellion in Kartasura Palace. According to Sayid [13], the king and all relics including Wayang Beber was evacuated from the Palace at Kartasura city in Central Java to Ponorogo in East Java. During this evacuation Wayang Beber was left in Pacitan which is located between Kartasura and Ponorogo. It was given to the local storyteller and kept as a sacred object by local community there.

In the conclusion, the origin of Wayang Beber of Pacitan figure visual style can be traced from the style of Wayang Batu on Panataran temple relief. It was the beginning of stylized figure applied in Wayang. The first transformation occurred when Islamic period began. The Hindu style of the figures was changed into the Islamic style on Wayang Kulit puppets. The style was transformed once more when it was applied on a painted figure of Wayang Beber of Pacitan paintings. The

transformation of Wayang medium and visual style can be seen in Figure 10.

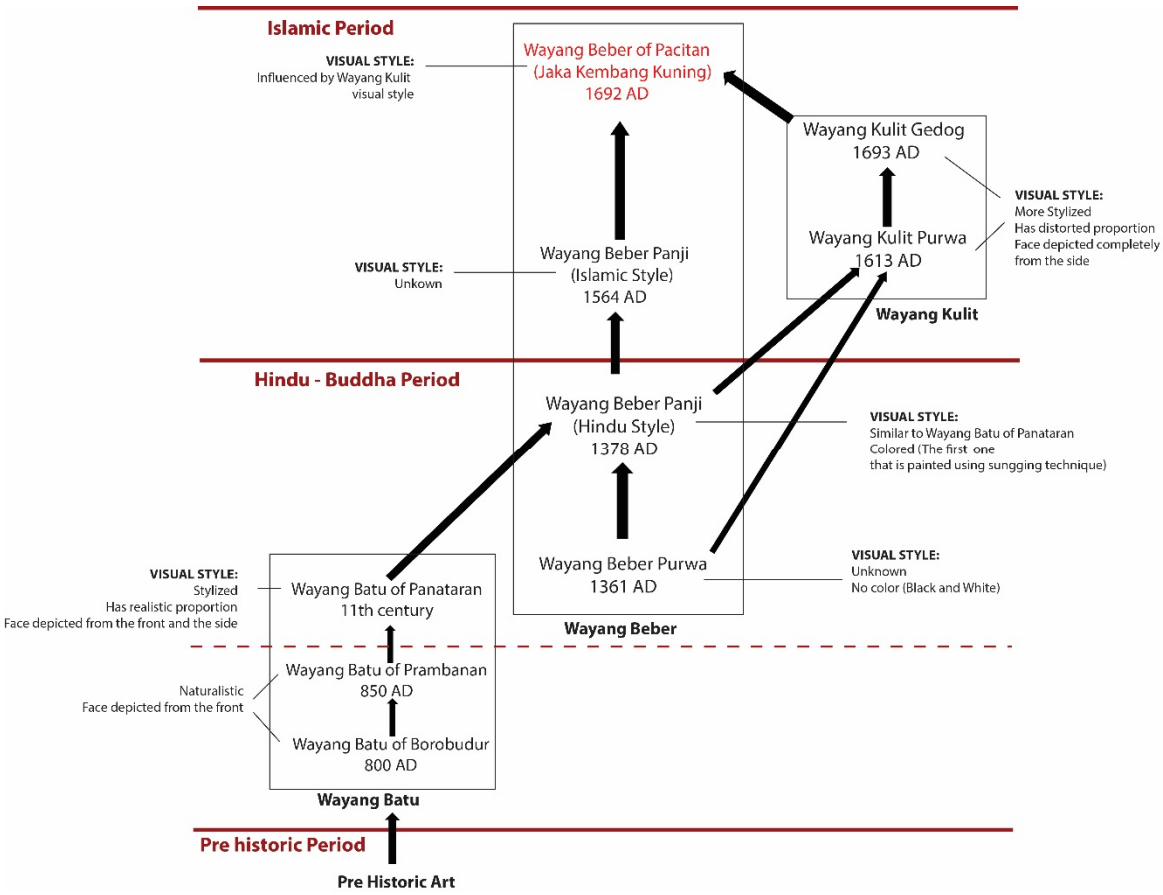


Figure 10. Transformation of Wayang medium and visual style

From the study, it is found that the change of religion affected the visual style of Wayang figure in Java. Wayang's visual no longer portrays human figures; now it symbolizes human personalities [80]. The shape of Wayang's body and attributes is considered as a symbol that describes the personalities of the Wayang characters.

The transformation of Wayang visual style is also caused by the change of Wayang medium. Wayang Kulit Purwa puppet has a very distinct shape. It has a big head, a long neck, wide shoulders and long thin arms. The entire body of the puppet is carved in a complex pattern. The reason behind this shape can be related to the necessity of Wayang Kulit performance. Sukasman, a Wayang storyteller and maker, has interpreted the shape of Wayang Kulit puppet [81]. He explained that in the Wayang Kulit performance, the shape of the puppet must be able to be identified easily by the audience. The thin and distorted puppet's body will help this identification. The long neck enables the head of Wayang to be easily seen from a distance. The wide shoulders and long arms are necessary so that the Wayang puppet's arms can be easily moved. Moreover, Wayang Kulit is performed behind a

screen, lit by light; most of the audience only sees shadows of the puppet (see Figure 11). The carved patterns make the shadow look more artistic and it helps audience to identify the Wayang character.

The shape of Wayang Kulit Purwa puppets is a prototype for the later development of Wayang art. It then became a visual style for Wayang figure which come from the later period, including Wayang Beber of Pacitan.

Figure 11. Silhouette of Wayang Kulit puppets in a performance[8] [82]

2.3 Features of Wayang Beber of Pacitan Figures Visual Style

As explained by Tabrani [83] , a visual style can be described by analyzing the visual elements, such as lines, colors, shapes, etc., which are used to form an image. After analyzing these elements, five features of Wayang Beber Pacitan figure visual style were found. Those are:

1. Outline drawing
2. Polychromatic color
3. Ornamental pattern
4. Distorted proportion
5. Stylized depiction

2.3.1 Outline Drawing

Outline drawing emphasizes the use of lines to form a shape. It focuses on the clarity of

[8] ©Jpatokal

the picture to convey a message rather than a resemblance to reality. The lines of Wayang Beber of Pacitan figures are clear, continuous, wiggly, and have variation of thicknesses. There are two kinds of lines, thick lines which are used for the outline and thinner lines which are used to depict details of the figure, such as body hair, skin wrinkles, or fold of cloth (see Figure 12). The lines have various colors depending on the color of the figures.

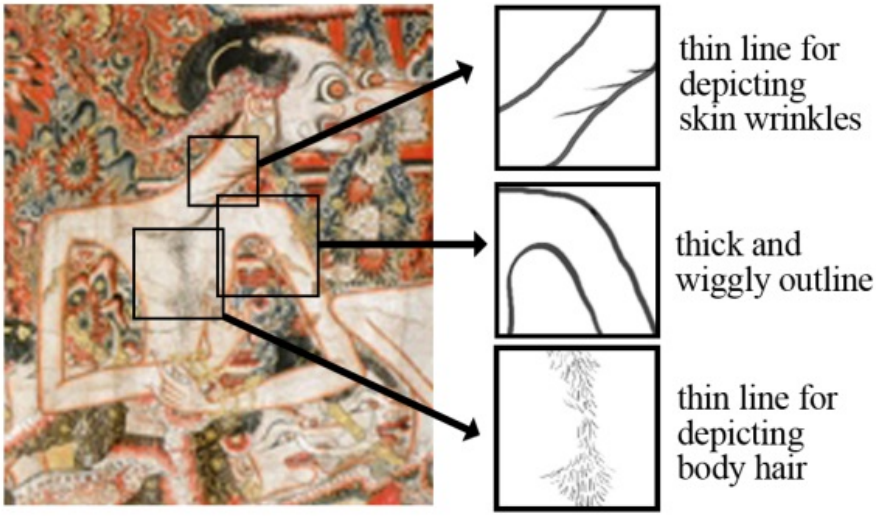


Figure 12.Lines features in Wayang Beber of Pacitan figure

2.3.2 Polychromatic Color.

Wayang Beber of Pacitan figure has colors with different hues. There are five color hues in the figures, such as red, green, yellow, white, and black. Each color is used in several values, for instance, there are red, light red and dark red. All colors are solid, they do not have a gradation. The transition from light color to dark is made by stacking colors one upon another. The unique color feature of Wayang Beber of Pacitan figure is produced by a specific Javanese traditional painting technique called *sungging*. The colors are added in a specific order started with the light colors and followed by darker colors.

Sukir [23] explains there are three types of coloring in *sungging* technique (see Figure 13):

1. Basic color,

   Basic color is called *byor*. It consists of one solid color. It can be found in most of Wayang Beber of Pacitan figures.

2. Layered Color

Layered Color is called *sorotan*. It is used to make gradient by piling up several colors with the same hues. It can be found on the textiles and tree images

3. Multiple Layered Colors,

   Multiple layered colors consists of colors with different hues. It can be found on the textile images of Wayang Beber of Pacitan figures.

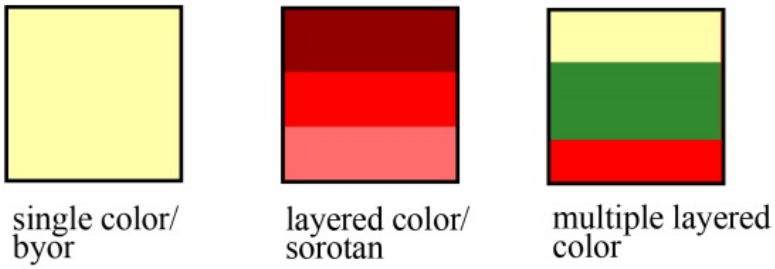


Figure 13. Color feature in Wayang Beber of Pacitan figure

2.3.3 Ornamental Patterns

Sungging is not just a technique for adding colors. It also includes a process to add patterns to certain areas of the painting. Usually it is added to a wide area that is colored with a basic color. On Wayang Beber of Pacitan, there are three types of patterns (see Figure 14). The first is flower pattern. The second is vines pattern. These patterns are used to portray Javanese traditional textile called batik; it is a typical textiles that are worn by Javanese. The third type is a thin line pattern. It is used to fill up the figure's clothes which are not covered by flower or vines patterns.

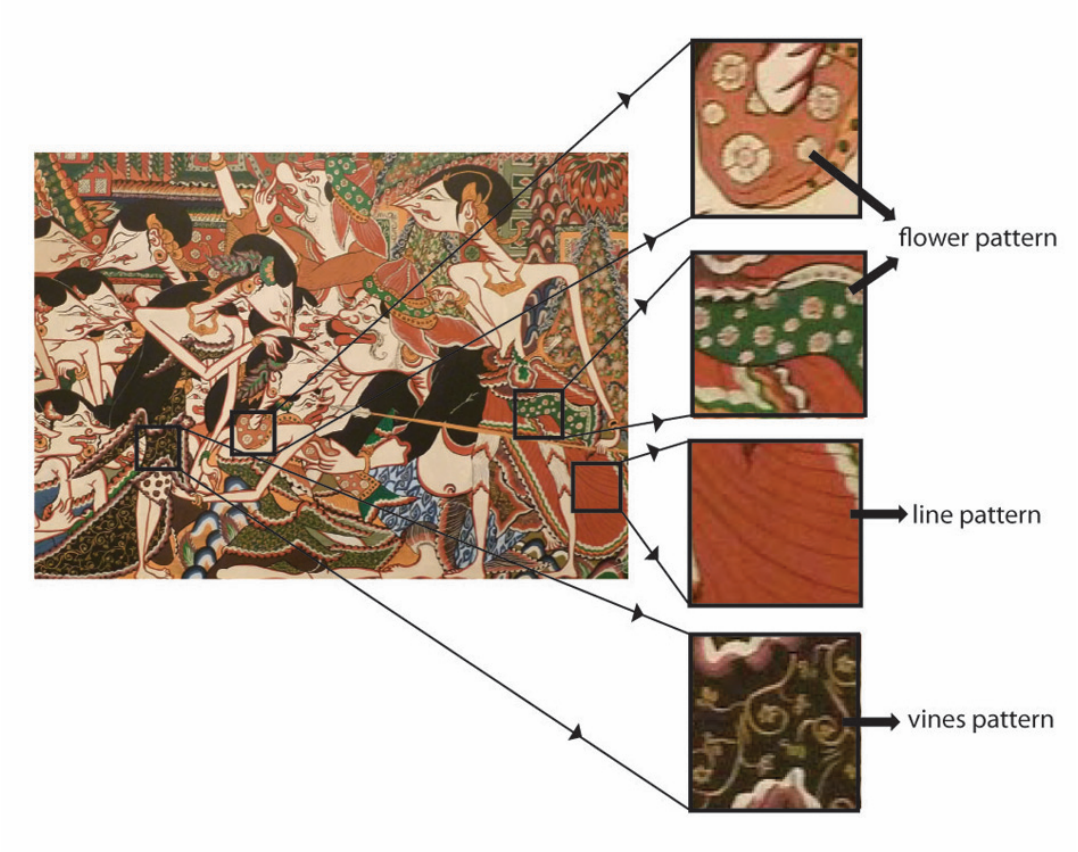


Figure 14. Patterns on Wayang Beber of Pacitan figure

2.3.4 Distorted proportion

Wayang Beber of Pacitan figures have a distinct shape. They have a big head, a long neck, and wide shoulders. The arms are longer than the legs. In the theory of visual language, it is called distorted depiction. This shape is derived from Wayang Kulit Purwa puppets. As explained in chapter 2.2, the shape is derived by the necessity of Wayang Kulit Purwa performance.

One of its distinguishable features is the head which is placed forward (see Figure 15). According to Sukasman [81], the purpose is so that when two figures are shown facing each other, they seem to communicate.

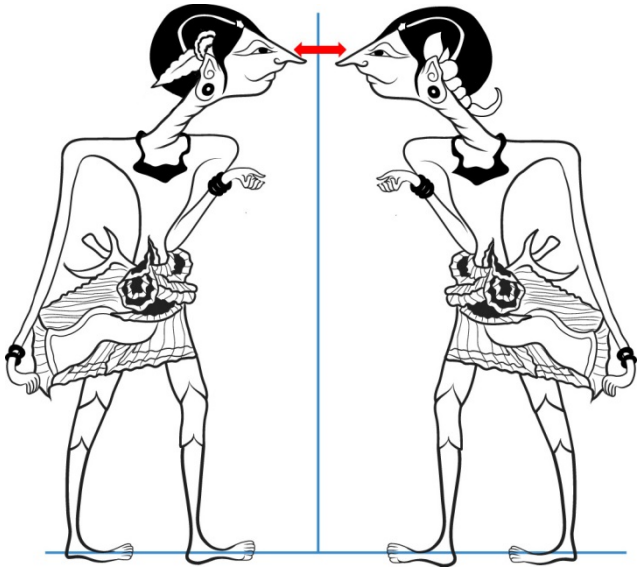


Figure 15. Two Wayang Beber figures seem to communicate when they are facing each other

However there are differences between the figures shape of Wayang Beber of Pacitan and Wayang Kulit puppets. These differences are caused by the change of Wayang medium, from puppet to painted scrolls. The shape of Wayang Beber of Pacitan figure is no longer limited by the necessity of puppet performance. Therefore the maker can create Wayang figure which has more realistic proportion but still follows Islamic rule.

These are the differences: Wayang Beber of Pacitan figures seem taller than Wayang Kulit figures. The arms of Wayang Beber of Pacitan figures are shorter. The position of their hands is above the knees, whereas the hand position of Wayang Kulit figures is below the knees. Shoulders of Wayang Kulit figures are wider; the right shoulder proportion is twice longer than the left shoulder. The right and the left shoulder proportion of Wayang Beber of Pacitan figures is more balanced (see Figure 16). The shape also has more curved contours.

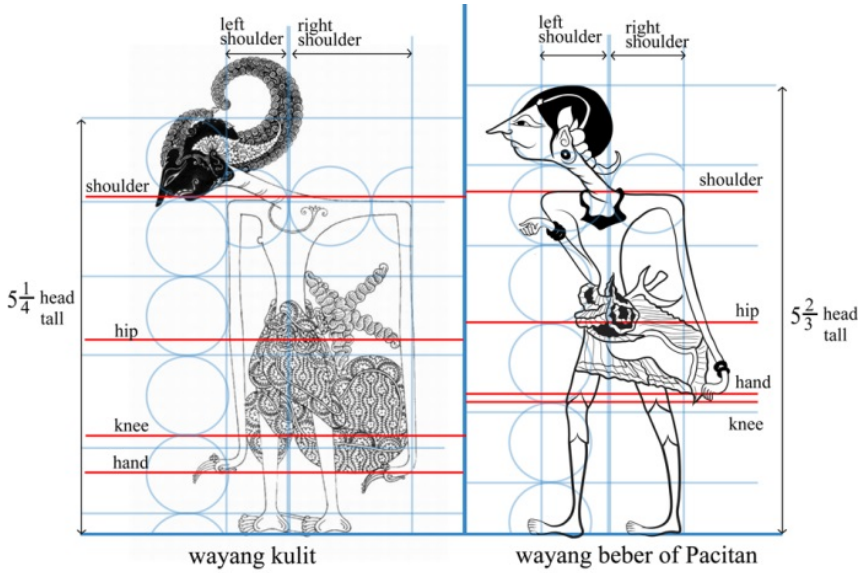


Figure 16. Comparison of Wayang Kulit puppet and Wayang Beber of Pacitan figure

2.3.5 Stylized depiction

Stylized depiction of Wayang Beber of Pacitan figure was made to follow Islamic view that prohibits realistic depiction of living creatures such as humans or animals.

Stylized depiction is a depiction that portrays an object according to particular formats, rather than realistic representation. In Wayang Beber of Pacitan figures, three formats are used. The formats are made based on the angle of depiction, size of depiction, and symbolic depiction.

2.3.4.1 Angle of Depiction

Generally, the figures in Wayang Beber of Pacitan painting are depicted from the side, but if they are observed more carefully, each body part of the figures seem to be depicted from various views (see Figure 17). It can be described as:

- The head, nose and mouth are depicted from the side.
- The eye is depicted from the front.
- The shoulders are depicted from the front.
- The body torso is depicted from the side.
- The arms and legs are depicted from the side.
- The feet are depicted from the side and above.

This way of depiction is called multiple views. Multiple views is a depiction of an image as if seen from different directions, different distances, or different time in one picture [83].

As mentioned before, the visual style of Wayang Beber Pacitan figure is derived from Wayang Kulit puppet. In the performance, Wayang Kulit puppet is shown as a shadow or silhouette. In this case, the multiple view depiction is used so that the silhouette of puppet's body parts can be easily recognized. Every body part of human figures can be easily recognized from certain angles. For instance, nose is easily recognized from the side, whereas eyes are easily recognized from the front.

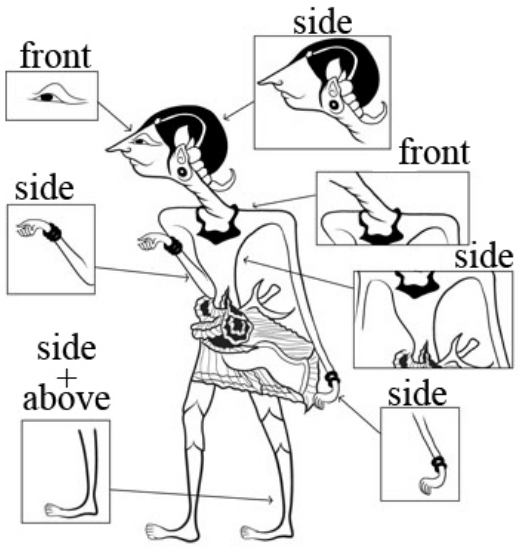


Figure 17. Multiple views in Wayang Beber of Pacitan figure

2.3.4.2 Size of Depiction

In Wayang Beber of Pacitan paintings, all the figures are drawn completely from the head to toe. This is called full body depiction. It is a typical depiction of figures in Indonesian traditional art. This type of depiction also can be seen in Panataran temple reliefs and Wayang Kulit puppets. All figures in Wayang Beber of Pacitan painting are always drawn in the same size. The figures that are close to viewers and the ones that are far from viewers do not have difference in size.

2.3.4.3 Symbolic Depiction

Wayang Beber of Pacitan figures were made not to depict a human physique, but to depict human personalities. The human personalities are symbolized by certain shapes of Wayang's body parts and attributes. To understand the symbols, theories of symbolism

in Wayang Kulit Purwa such as explained by Sayid [84], Purwadi [80], and Long [85] are studied.

Symbolized personalities in Wayang Kulit Purwa can be recognized from their character types. According to Long, the character types are determined by the iconographic features of its figures. The major determinants are body size which consists of four sizes, eye shape that includes seven major types (see Figure 18), mouth shape that also has seven types (see Figure 19), and tilt of head which consists of three kinds of positions (see Figure 20). Other important features include stance, shape of nose (see Figure 21), and adornment.

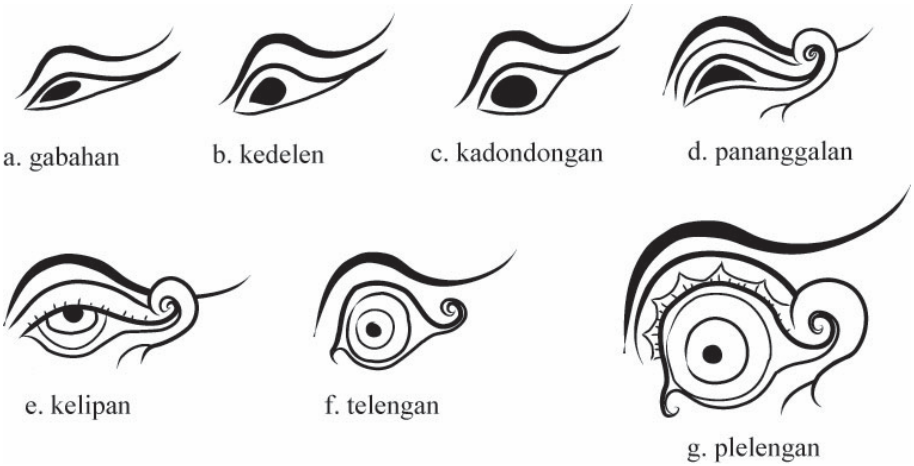


Figure 18. Types of Wayang's eye shape

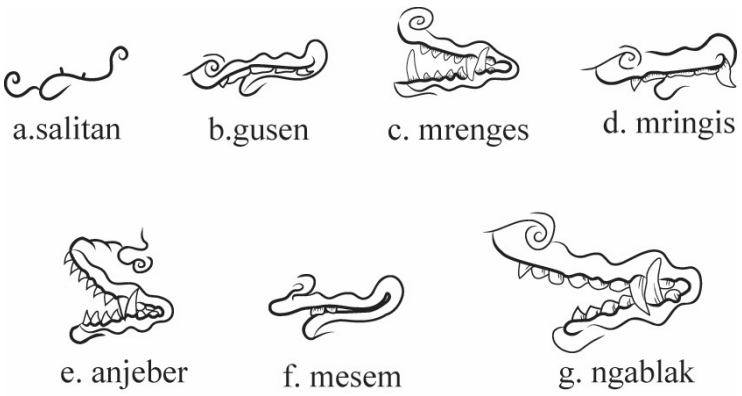


Figure 19. Types of Wayang's mouth shape

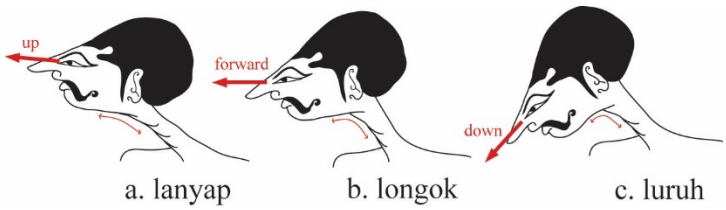


Figure 20. Types of Wayang's tilt of head

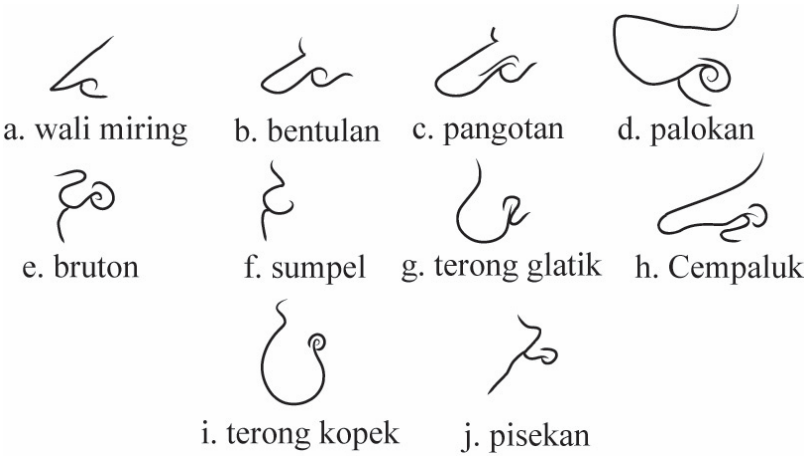


Figure 21. Types of Wayang's nose shape

In this research, the characters of Wayang Beber of Pacitan are categorized based on body size, eye shape, types of mouth, nose shape, and tilt of the head. These features are used to determine characters' personalities. The adornment which is used to determine status and social class of the character is excluded. The stance is also excluded because it is difficult to be identified in Wayang Beber of Pacitan figures. The categorization of the important characters can be seen in table 2. The identification of characters' iconographic features in each group can be seen in table 3.

table 2. Categorization of character in Wayang Beber Beber of Pacitan

Group	Character Picture	Character Name
I	 1 2 3 4	1. Dewi Sekartaji (female) 2. Jaka Kembang Kuning (male) 3. Sedahrama (male) 4. Retno Mindaka(female)
II	 1 2 3	1. Gandarepa (male) 2. Ni Cona Coni (female) 3.Retno Tenggaron (female)
III	 1	1. King of Kediri (male)
IV	 1 2	1. Arya Jeksa Negara (male) 2. Kili Suci (female)
V	 1	3. King Klana (male)
VI	 1 2	1. Demang Kuning (male) 2. Kebo Lorodan (male)

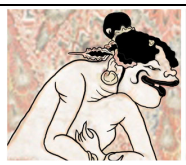
Group	Character Picture	Character Name
VII	 1	1. Tumenggung Cona Coni (male)
VIII	  1 2	1. Naladerma (male) 2. Tawangalun (male)

Table 3. Iconographic features of figures in Wayang Beber of Pacitan

	Iconographic Features				
Group	Body Size	Eye Shape	Mouth shape	Nose shape	Tilt of Head
I	Small	gabahan	salitan	wali miring	luruh
II	Small	gabahan	salitan	wali miring	longok
III	Small	kedelen	salitan	Wali miring	luruh
IV	Small	kedelen	salitan	Wali miring	longok
V	Medium	telengan	salitan	benthulan	lanyap
VI	Big	telengan	gusen	pangotan	lanyap
VII	Medium (fat)	telengan	salitan	benthulan	longok
VIII	Small (fat)	kelipan	mesem	Bruton & terong glatik	longok & lanyap

Long explains that Wayang Kulit characters can be classified into six types which are associated with specific personalities. The first type is identified as *alus* or refined character, which has reserved and polite personalities. The second type is identified as gallant or *gagah*, third type is rude or called *gusen*, fourth type is ogre and giant character called *danawa*, fifth type is a simian character called *wanara*, and the sixth is clown-servants character called *dhagelan*.

This classification is applied to Wayang Beber of Pacitan characters and four classes of character are found. First, the characters in group I, II, III, and IV (see table 2) are classified as a refined type. Main features that determine this type is the character's body size. The character has a smallest body among the six types. The body is slender and has a feminine appearance. Generally, refined characters have a suave and polite personality. This type is divided into two, the character with *gabahan* eye, and character with *kedelen* eye. Each of them has two variations, character with *luruh* tilt of head, and

character with *longok* tilt of head. Variation of eye shape and tilt of head signify degrees of refinement.

Characters with *kedelen* eye have more aggressive personality than characters with *gabahan* eye. Characters with *longok* tilt of head are more aggressive than the character with *luruh* type. Therefore, characters with *gabahan* eye and *luruh* tilt of shape are the most refined characters; it is followed by the characters with *gabahan* eye and *longok* character, and then the characters with *kedelen* eye and *luruh* tilt of head. The characters with *kedelen* eye and *longok* tilt of head are the most aggressive characters in this class.

Second, the characters in group V and VII are classified as a gallant type. Characters in group VII have special distinguishable features. They have fat body shape and humped gesture that cannot be found in any other Wayang Beber character. These features make the characters are difficult to be categorized. However based on their general features such as a medium body size, and *salitan* mouth shape, these characters can be included in the gallant type. The characters in this type are strong and have a brave personality. The variation of tilt of head signifies degrees of aggressiveness. *Lanyap* type is more aggressive than *longok*.

Third, the characters in group VI are significantly classified as a rude type. This type has a big muscular body, signifies strong, rude, and aggressive character. Fourth, the characters in group VIII can be classified as a clown-servant type. This type is the most diversified category. Each character in this type differs from one to another. However clown-servant characters can be easily distinguished from the other class of characters. This class signifies various personalities.

2. 4 Concluding Remarks

In this chapter the history of Wayang Beber of Pacitan has been elaborated. Therefore, the relation between Wayang Beber of Pacitan and other types of Wayang such as Wayang Kulit Purwa can be understood. The relationship provides important information regarding the evolution of Wayang visual style.

It can be concluded that the visual style of Wayang Beber of Pacitan figures is a modification from previous types of Wayang. It occurred because of two main factors:

1. Cultural change in Javanese society.

   The inclusion of Islam religion has a great impact on Javanese culture including Wayang art. It resulted in changes of function, and representation of Wayang. It created a distinct feature of Wayang figure. This feature is applied in Wayang Beber

of Pacitan. It is called stylized depiction. Stylized depiction is performed to avoid a realistic human depiction which is forbidden in Islam. Stylized depiction is done based on two approaches. The first approach is distorted proportion. Wayang figure proportion is distorted in a certain way so that it does not resemble a realistic human figure. The second approach is symbolic depiction. The figures are created based on iconographic symbolism. It is used to symbolize human personalities that relate to certain religious messages.

2. The innovation in the Wayang art.

The medium of Wayang has been developed for centuries, from a shadow performance to articulated leather puppets. This development brings changes not only to the performance technique but also to the visualization of Wayang. The visual style of Wayang is determined by the characteristics of its medium, as well as the necessity of its performance.

Chapter 3.
Generating Wayang Beber of Pacitan Character's Outline Using Renderman Interface

3.1. Overview

This chapter discusses technical issue to render the outline of Wayang Beber of Pacitan characters' figure in 3DCG. The image is rendered using Renderman, an API (Application Programing Interface) designed by Pixar studios for animation production. This chapter explains the development of the shader for generating an outline that can be applied in the Renderman interface.

3.2. Features of Wayang Beber of Pacitan Outline

The most important thing in non-photorealistic rendering is defining the art direction. In order to do this, a good reference image is needed. For this chapter, a replica of the Wayang Beber of Pacitan painting is used as a reference image. This replica is made by a modern artist, member of the Wayang Beber Metropolitan community in Jakarta, Indonesia (see Figure 22).

The replica has to be used because the original Wayang Beber of Pacitan paintings are in a poor condition and difficult to be accessed. The quality of the replica made by a member of Wayang Beber Metropolitan community is very good , it resembles the original paintings very well. Therefore this replica is proper to be used as a reference image. The fifth scene of Wayang Beber of Pacitan paintings' replica is used as a sample for the analysis. To understand features of the outline, the Gandarepa character figure on this scene is examined (see Figure 23).

Figure 22. The replica of the Wayang Beber of Pacitan painting[9] [86]

Figure 23. Figure of Gandarepa

Base on the study, three important features of the figure's outline are found. Firstly, the outline is relatively thick. There is no information as to how thick the outline should be made, but certainly it should be thick enough so it can be seen clearly from a distance. The thick outline serves to emphasize the characters' shape, and to separate it from the background.

Secondly, the outline has a variation of thicknesses (see Figure 24.). The outline thickness, usually called the line width, is not uniform. The outline is made by hand. During the painting process, the pressure of the hand on the brush may change, and as

9 ©Wayang Beber Metropolitan Community

a result the line width changes (see Figure 25a). Thomas Strohotte and Stefan Schlechtweg described this feature as incorrectness quality of human drawing [87].

The third feature is wiggliness. It is defined as irregularities that occurr on the outline shape (see Figure 24). This is also one of the incorrectness qualities of human drawing. Lines drawn by a human are never completely straight, especially if the maker does not use any aids, such as a ruler. The lines are more or less wiggly (see Figure 25b). The wiggliness is caused by a small irregular movement of the human hand when he or she is drawing the image; the wiggliness also can be caused by the paper structure [87].

This research intends to generate the outline using 3DCG. In contrast to human drawing, 3DCG generate perfectly smooth and straight lines with a uniform thicknesses, as shown in the works by Hajagos [88], De Wolf [89], and Apocada et al. [90]. Therefore a new algorithm to generate lines with incorrectness qualities is needed.

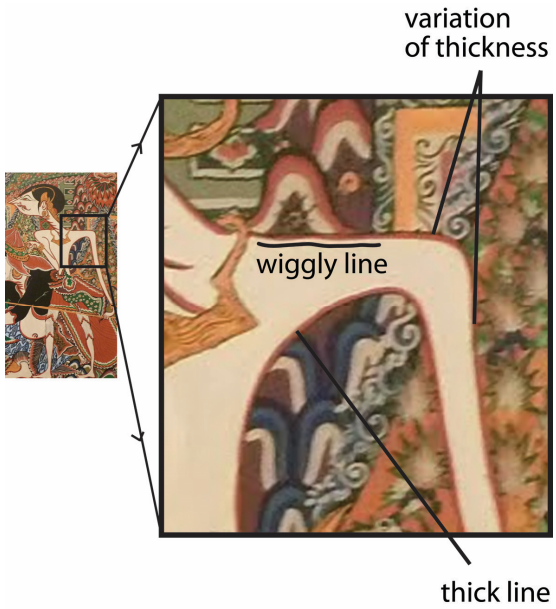


Figure 24. Outline of Gandarepa figure

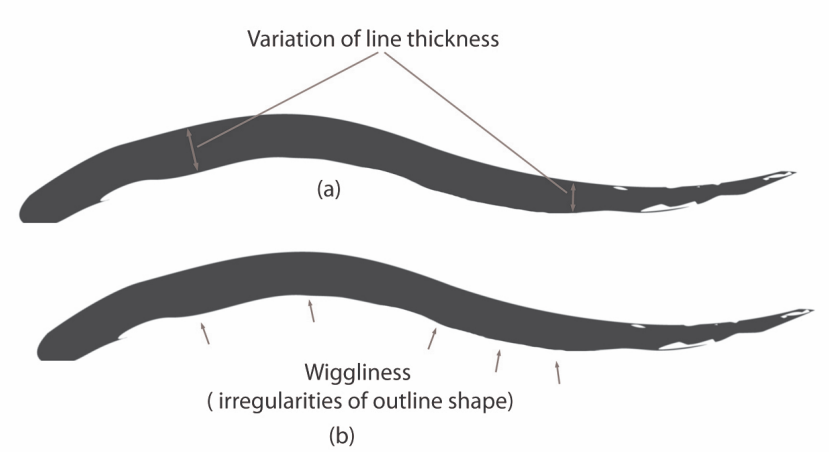


Figure 25. Sample of hand drawn line. (a) Variation of thickness in hand drawn line, (b) wiggliness of hand drawn line

3.3. Related Works

This research tries to develop a shader that can generate the Wayang Beber of Pacitan outline in a 3DCG model and works on Renderman interface. The Renderman is used because it can produce a high quality image, it has great programmability (provides a great amount of control) and it is designed for animation.

There are two shaders in the Renderman interface that can be used to generate an outline. The first is cel shaders, developed by Apocada and Gritz [90], and the second one is ID outline shader, developed by Ivan De Wolf [89] . However these two shaders do not fit for the purpose of this reseach. Although it can generate a variation of thicknesses, the Apocada and Gritz's shader sometimes produce an undesired dark area on the rendered image (see Figure 26a). While, Ivan De Wolf's ID outline shader can produce a good and clean image, but it does not generate variation of thicknesses and wiggliness (see Figure 26b). A new shader to generate the outline is needed.

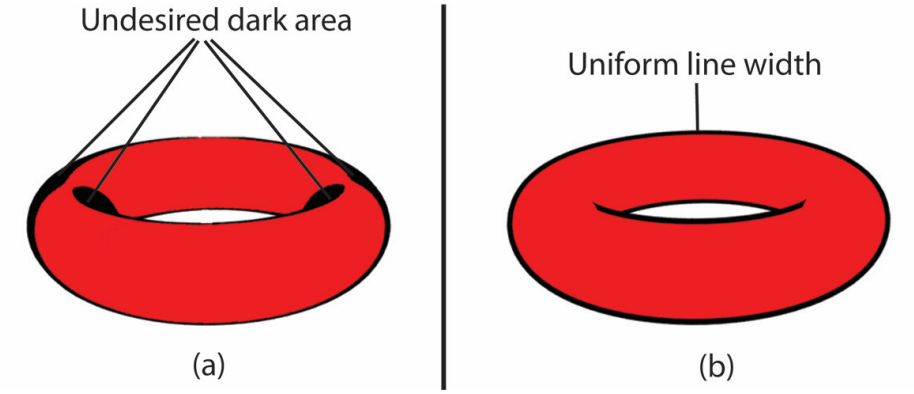


Figure 26. (a) Rendering result of Apocada and Gritz's shader. (b) Rendering result of Ivan De Wolf's shader

The important aspect for generating an outline on a 3DCG object is silhouette edges. The outline is generated by finding and displaying the silhouette edges. One of the methods to do this is using a two-pass rendering such as used by Gooch [91] and Raskar [40].

The two-pass rendering method works in an image space. This method uses two layer of polygons; the first layer is a layer of front facing polygons and the second layer behind is a layer of back facing polygons. Back facing polygons are rendered first, and then the front facing polygons are rendered on the top. The intersection of these two layers in the image space creates silhouette edges. Raskar and Cohen increased the area of the intersection by pulling the back facing polygons slightly forward towards the camera. This method is easy to implement. The time to write and debug the code was very short, the rendering speed was fast, and the visual quality was good.

Raskar and Cohen's method is suitable for this research. Similar approach is possible to be developed and applied in the Renderman interface. It is comparable with the algorithm proposed by Ivan De Wolf. Nevertheless, instead of using two layers of images in the image space, De Wolf's algorithm used two objects in the object space. It used two identical objects; one of the objects was scaled and rendered as an outline. This shader can produce a thick outline efficiently. It does not need to be composed after rendering process. However it cannot produce the incorrectness qualities of a human drawing. In In this research, a new shader is developed based on the algorithm proposed by Ivan De Wolf. The new algorithm is implemented in Renderman Shader Language (RSL).

3. 4. Generating The Wayang Beber of Pacitan Character's Outline

To generate the outline, firstly, the object has to be duplicated. Then results of the

duplication are labeled as object A and object B. Object A will be rendered as outline and object B will be rendered as fill. The algorithm is explained as follows:

A. rendering fill (object B)

To create the random wiggliness :

1. Input s and t; the texture coordinate.
2. Input W; the frequency of wiggliness
3. Scale the s and t by multiplying them with W.
4. Apply Perlin noise function to scaled result of S and T to get a random number (H).
5. Input K; the amplitude of the wiggliness
6. Scale H by multiplying it by K
7. Calculate Nn by normalizing the surface normal.
8. Randomly displace the surface point P in the direction of its normal using this following equation:

$$\vec{P}' = \vec{P} - \vec{N}n \times H \times K$$

Shade the fill color :

9. Input Cs (the fill color)
10. Input Os (the fill opacity)
11. compute the Ci (output color)using this following equation

    Ci = Cs × Os

B. Rendering Outline (Object A).

Displace the surface

1. Input width
2. Calculate Nn by normalizing the surface normal.
3. Add the new vector V
4. Compute D; the dot product between normalized V and Nn.
5. Input MinWidth; the minimum width value of the line
6. Compute S; the parameter to create a displacement ramp using this equation:

   S= (1-D) + D × MinWidth
7. Displace the surface point P in the direction of its normal using this equation:

$$\vec{P}' = \vec{P} + \vec{N}n \times (width + (width \times S))$$

Creating the random wiggliness

8. Input s and t; the texture coordinate.
9. Input W; the frequency of wiggliness
10. Scale the s and t by multiplying them with W.
11. Apply Perlin noise function to scaled result of S and T to get a random number (H).
12. Input K; amplitude of the wiggliness
13. Scale H by multiplying it by K
14. Randomly displace the surface point P in the direction of its normal

$$\vec{P}' = \vec{P} - \vec{N}n \times H \times K$$

Shade the outline

15. Detecting silhouette edges by computing D1, the dot product between Nn and normalized I; the viewing direction vector.
16. If D1 > 0, then set the output opacity to 0
    If D1 < 0, then set the output opacity to 1
17. Input Cs; the outline color
18. Set the Output color
    Ci = Cs;

The following is the explanation of the algorithm.

3.4.1. Ivan De Wolf's Outline Algorithm

In the outline algorithm written by Ivan De Wolf [89], the surface of the object A is displaced by moving the surface points in the direction that is parallel to their normal. Normal is a vector that describes the surface orientation. The surface normal can have varying lengths, so it must be normalized to ensure its length does not affect the displacement.

In the displacement process, the surface points are moved with a distance that is equal to the value that is defined as line width. The process is described in the following equation:

$$\vec{P}' = \vec{P} + \vec{N}n \times \text{width} \qquad (1)$$

Where $\vec{P}'$ is the new surface point, $\vec{P}$ is the initial surface point, $\vec{N}n$ is the normalized normal, and the width is the displacement distance.

After displacement, the displaced object (object A) will be bigger than object B.

Since the position coordinate of the two objects are exactly the same, object B will be placed inside object A. So, object B will be invisible (see Figure 27).

To make object B visible, the front facing polygons of object A must be invisible. The orientation of the object A polygons can be detected by computing the dot product between their surface normal and the viewing direction vector [92]. This process is described in:

$$\vec{N}n \bullet \vec{I}n = |\mathrm{Nn}|\,|\,\mathrm{In}\,|\cos(\theta) \qquad (2)$$

Where $\vec{N}n$ is the normalized normal, $\vec{I}n$ is the normalized viewing direction vector, and θ is the angle between two vectors.

If the dot product is positive then the polygon is back facing, otherwise if the dot product is negative then the polygon is front facing. After the orientation of the polygons is known then the opacity of the polygons can be set. The back facing polygons opacity is set as 1, so the back facing polygons are visible, and the front facing polygons opacity is set as 0, so the fornt facing polygons are invisible. As a result the object B that is placed inside object A is visible. The viewer will see the back facing polygons of the object A as the object's outline (see Figure 28).

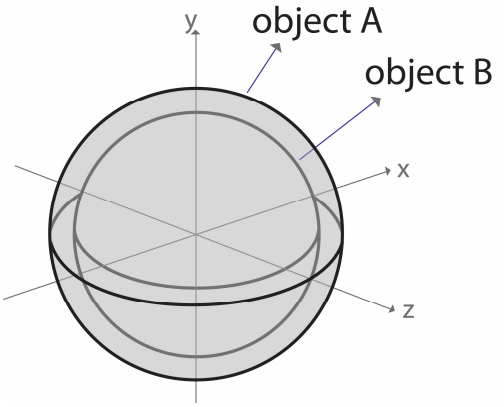


Figure 27. Object B was placed inside object A after displacement

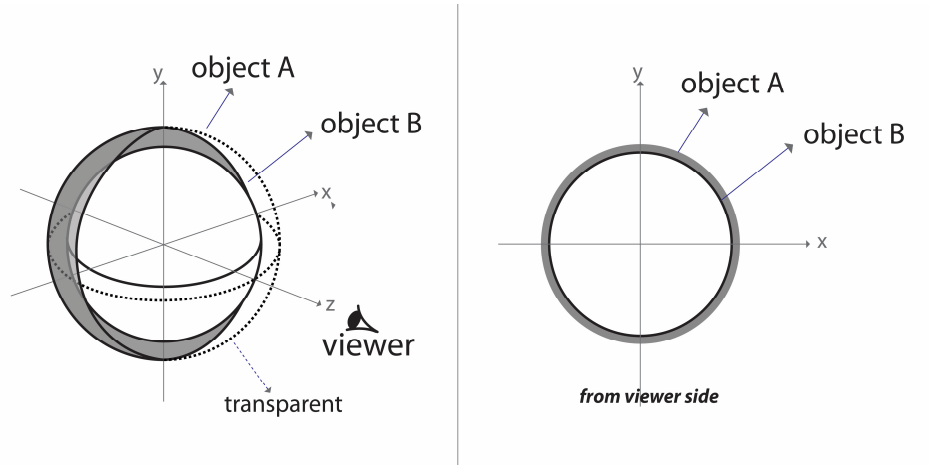


Figure 28. The front facing Polygon of object A is invisible; object B inside object A is visible

3.4.2. Creating Variations of Line Thicknesses

Ivan De Wolf's outline shader generates a smooth outline with a constant thickness. The outline of the Wayang Beber of Pacitan character has a variation of thicknesses and wigglinesses. Ivan De Wolf's outline shader is modified to obtain those qualities. For achieving variation of thicknesses, every surface points of object A should be moved in various distance. Thus, a displacement ramp is needed. The displacement ramp is created based on the surface point position. Using the displacement ramp the distance of surface point displacement could be changed gradually.

To create a displacement ramp, a new vector is added as parameter. The direction of the new vector can be various. Its x and y coordinate can be any number, but the z coordinate has to be 0. In this research a vector that points downward, perpendicular with the x axis is added, as seen in Figure 29.

Then the dot product between the normalized new vector $\vec{V}n$ and the normalized surface normal $\vec{N}n$ is computed as in:

$$D = \vec{V}n \bullet \vec{N}n \qquad (3)$$

Where D is the dot product between the normalized new vector $\vec{V}n$ and the normalized surface normal $\vec{N}n$.

If the normalized new vector $\vec{V}n$ and the normalized surface normal $\vec{N}n$ are perpendicular, the dot product will be 0 and if they are parallel the dot product

will be 1.

A new parameter to create the displacement ramp is obtained using the following equation:

$$S = (1-D) + D \times 0.1 \quad (4)$$

Where S is a new parameter to create the displacement ramp. Then the displacement ramp is created using the following equation:

$$\vec{P}' = \vec{P} + \vec{N}n \times (\text{width} + (\text{width} \times S)) \quad (5)$$

Where $\vec{P}'$ is the new surface point, $\vec{P}$ is the initial surface point, $\vec{N}n$ is the normalized normal and the width is the displacement distance.

As a result object A displaced gradually and the variation of line thicknesses is obtained (see Figure 30).

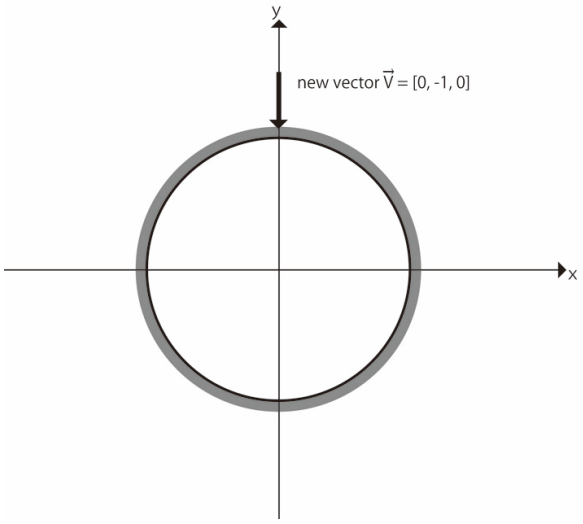


Figure 29. The New Vector

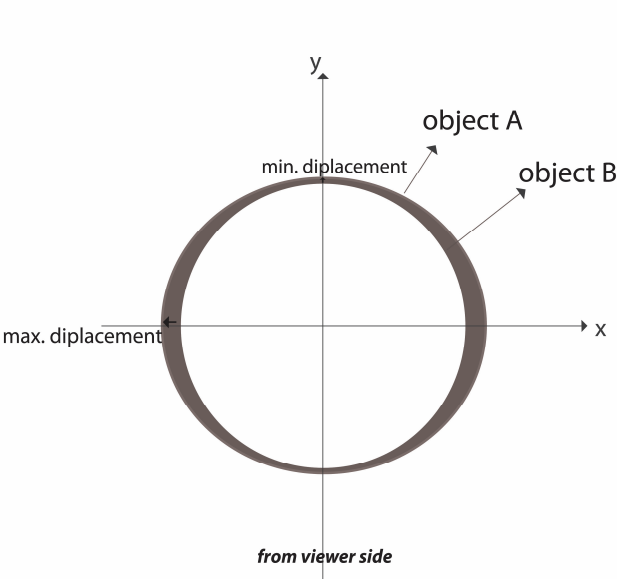


Figure 30. Displacement ramp

3.4.3. Creating Wiggliness

The surface points are displaced once more using random numbers to obtain wiggliness.

Random numbers are generated using the Perlin noise function. This noise function generates values which can be used to create randomness on a surface [93]. The noise function can take a varying number of parameters, and return them in a range of values. The values returned are guaranteed to be between 0 and 1. Nevertheless, in practice the output values are generally in the range of 0.27 to 0.7. The Perlin noise function is applied to the texture (s and t) coordinates. The default values of s and t generate a low noise frequency. Therefore the values are scaled by multiplying them with a new parameter called *W*. To control the amplitude of the noise, the noise function output is scaled by multiplying it with a new parameter called *K*. Each surface point is displaced using the output of this noise function. As a result a wiggly outline is achieved (see Figure 31).

3.5. Evaluation

3.5.1 Rendering Experiments

The proposed shader can simulate the Wayang Beber of Pacitan outline which has incorrectness qualities of human drawing (see Figure 31). Several parameters are added to control attributes of the outline, such as the line width, the variation of thicknesses,

and the wiggliness.

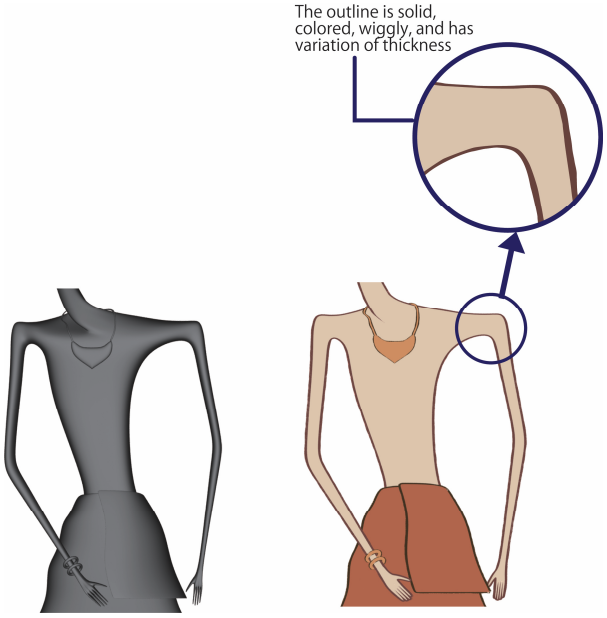


Figure 31. Rendering result of the proposed shader

A series of experiments were performed by rendering the object several times using different values to get optimum results. Comparison of the rendering result with different thickness values can be seen in Figure 32. Figure 32a was obtained by thickness value of 0.3; Figure 32b was obtained by thickness value of 0.1; and the Figure 32c was obtained by thickness value of 0.05. The most proper result is shown in Figure 32b.
Comparison of the rendering result with different thickness variation values can be seen in Figure 33. The outline with uniform thickness can be seen in Figure 33a which was obtained by a thickness variation value of 1. Figure 33b was obtained by the thickness variation value of 0.1. Figure 33c was obtained by the thickness variation value of 0.005. Figure 33d was obtained by the thickness variation value 0. The most appropriate result is shown in Figure 33b.

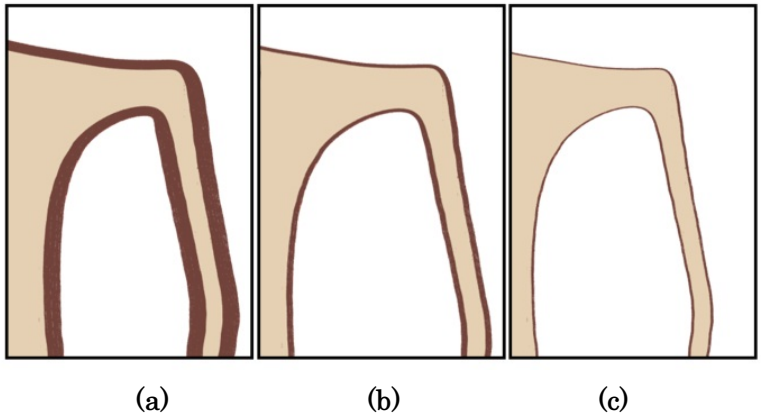


Figure 32. Comparison of rendering result using different thickness parameter

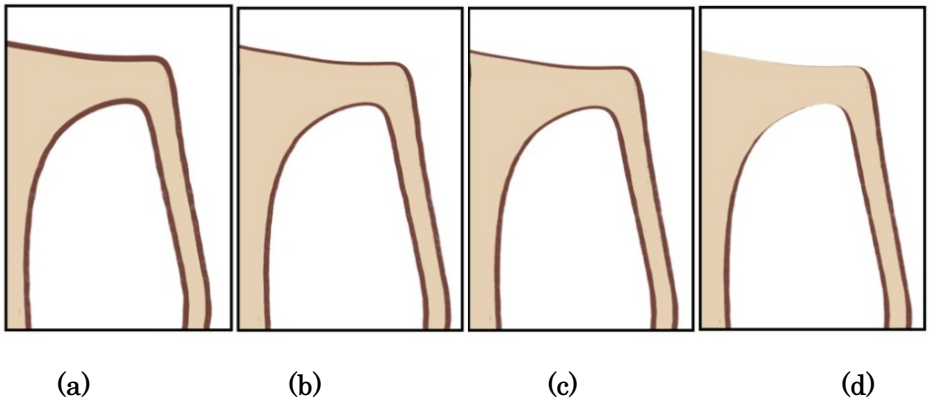


Figure 33. Comparison of rendering result using different thickness variation parameter

Figure 34 shows the result of experiments applying various values of wiggliness. Figure 34a was obtained by the wiggliness value of 0. Figure 34b was obtained by the wiggliness value of 0.6. Figure 34c was obtained by the wiggliness value of 1. Figure 34d was obtained by the wiggliness value of 1.5. The best result is shown in Figure 34b.

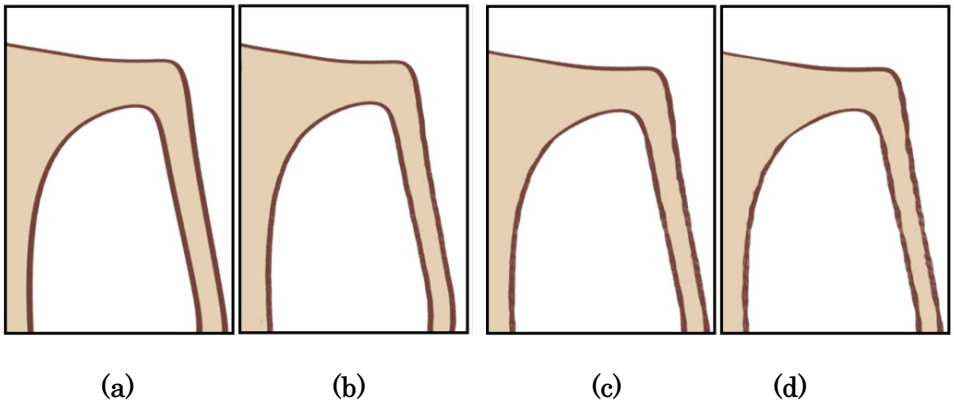


Figure 34. Comparison of rendering result using different wiggliness parameter

3.5.2 Authorial Subjective Evaluation

There are three rules which were used to evaluate the proposed shader:

1. The shader should be able to generate a relatively thick outline.
2. The shader should be able to generate an outline that has a variation of thicknesses.
3. The shader should be able to generate an outline that has wiggliness.

The image rendered with the proposed shader (see Figure 35) has all the attributes which are specified in the rules. It shows that the shader is able to obey all the rules.

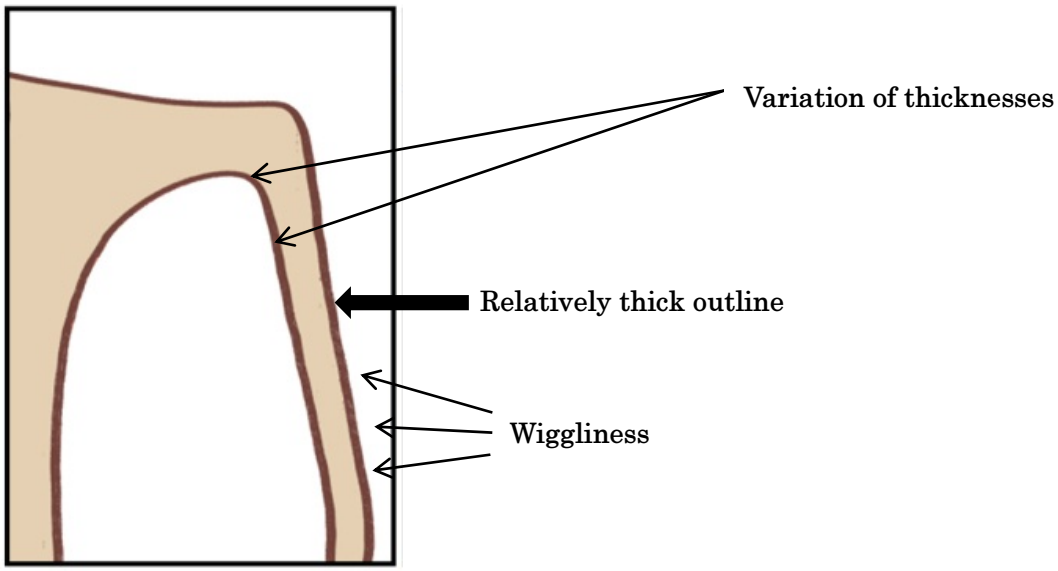
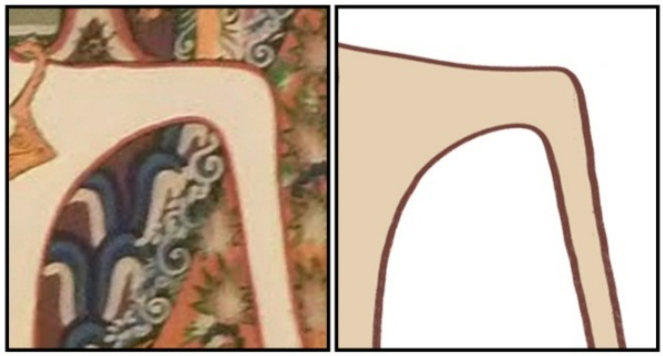


Figure 35. Attributes of the image rendered with the proposed shader.

For the evaluation, the CG image rendered using the proposed shader was compared to a reference image which was made by hand. As shown in Figure 36, the image rendered by the proposed shader resembles the reference image properly. Figure 37 and Figure 38 shows that there are slight differences between the rendered images and their references.

However the differences are caused by the shape of the 3DCG model. The proposed shader is able to simulate all the attributes which are needed to create Wayang Beber of Pacitan figure's outline.



(a) (b)

Figure 36. Comparison between the reference image (a) and the rendering result (b)

Figure 37. Comparison of the refence image and a Wayang figure's head rendered using the proposed shader

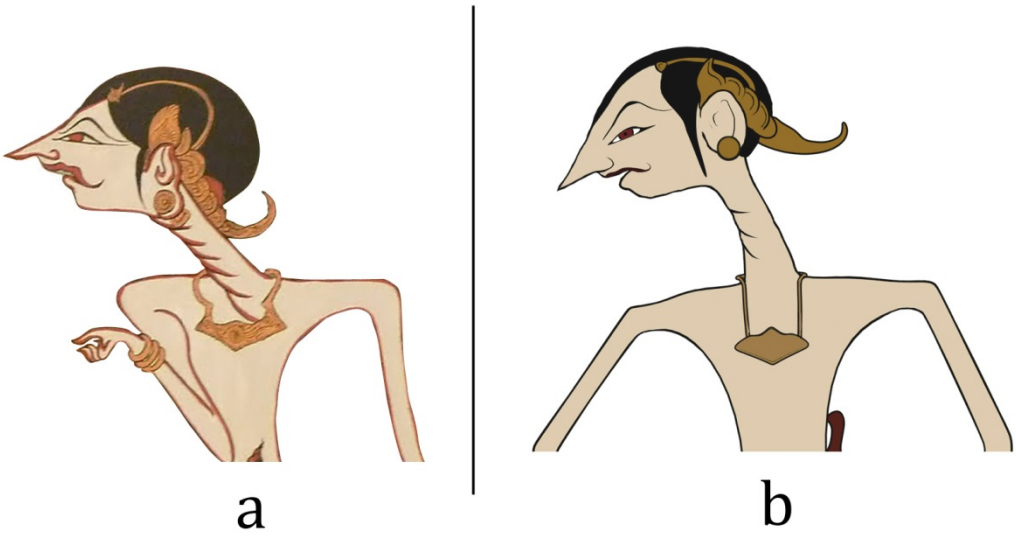


Figure 38. Comparison between the reference image (a) and a Wayang figure rendered using the proposed shader (b)

3.5.3 Shaders Comparison

Four different shaders were used to render several images. Then the results were compared (see Figure 39 and Figure 40). The shader developed by Anthony Apocada and Larry Gritz (see Figure 39a and Figure 40a) generated an outline with a variation of thicknesses. However, it also produced unwanted shadow or dark area in high curved edges. The contrast between the thick part and the thin part of the line is also difficult to be controlled.

The shader developed by Ivan De Wolf (see Figure 39c and Figure 40b) generated a smooth thick outline. The rendering result is good, but not suitable for our purpose. The outline generated using this shader has a uniform thickness; it also does not have wiggliness.

Maya Toon shader generated a good outline (see Figure 40c). It has a variation of thicknesses and wiggliness. However the wiggliness seems unnatural. The outline is wiggly but the object itself is smooth.

The proposed shader (see Figure 39d and Figure 40d) generated the most proper result. It is able to generate a relatively thick line with a variation of thicknesses. The wiggliness seems natural. Both the object and the outline are wiggly.

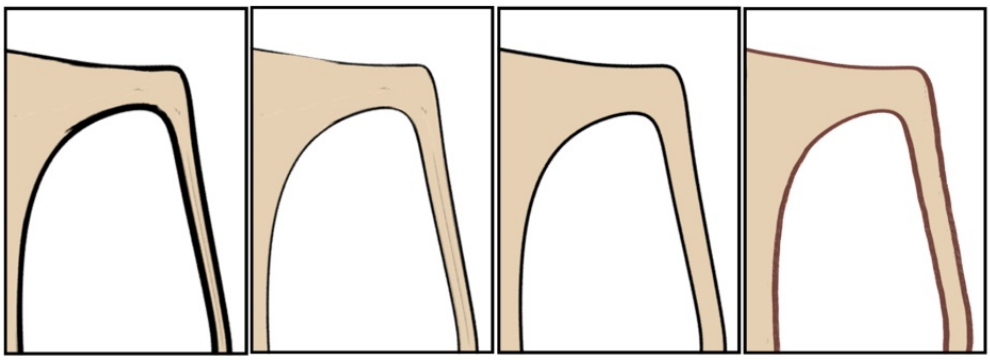


Figure 39. Comparison of rendering result using different shaders. (a),(b) Apocada and Gritz"s shader, (c) ID outline shader, (d) our shader.

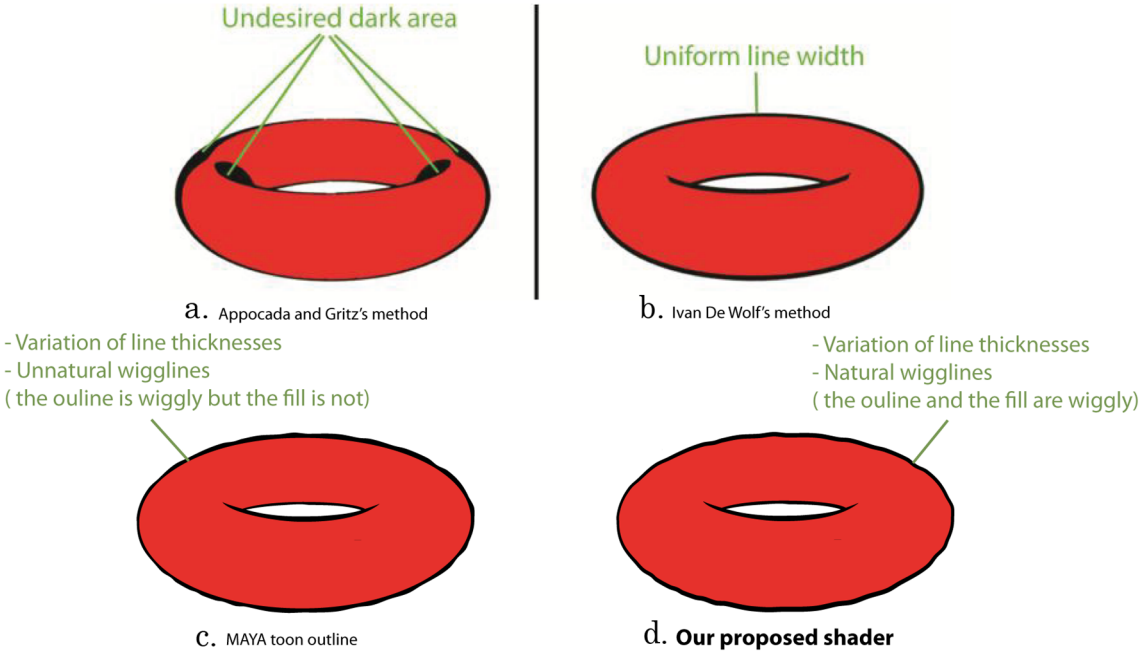


Figure 40. Comparison of rendering result using different shaders.

3.6. Concluding Remarks

There are two subjects elaborated in this chapter: the first one is the outline features of Wayang Beber of Pacitan, and the second one is the proposed algorithm to simulate the features.

The outline of Wayang Beber of Pacitan has typical features that are identified as

incorrectness qualities of human drawing. Those features are variation of thicknesses and wiggliness. To simulate those features, this research proposes an object-based silhouette rendering algorithm which incorporates a non-uniform point displacement and Perlin noise function.

The image rendered by the proposed shader is able to be distinguished from the original painting. However based on the analysis, the problem lies on the 3DCG model, not on the rendering method. The proposed shader is able to keep and simulate the features of Wayang Beber of Pacitan outline. For the purpose to reproduce Wayang Beber of Pacitan painting for preservation, this proposed shader works properly.

Chapter 4.
Shader Based Generated Ornamentation for Rendering Wayang Beber of Pacitan Characters' Cloth Pattern

4.1 Overview

This chapter describes a proposed technique to generate patterns of Wayang Beber of Pacitan characters' textiles. In CG production, the common technique to make a pattern on a surface is using a texture map. However, this technique is unsuitable for this project. When using the texture map, the pattern is obtained from a bitmap file. Modifying the pattern can only be done by changing the bitmap file. To simulate Wayang Beber of Pacitan picture, the pattern must be modified several times. There are many characters in Wayang Beber of Pacitan that have different cloth patterns; some of them have similar patterns with a few variations. Using different bitmap files for each character will result in a big file size. Moreover, modifying a bitmap file one by one will take plenty of time.

Figure 41. Various patterns of Wayang Beber of Pacitan characters' clothes

For the project, a different system to create a pattern on 3DCG surface is needed. The system should allow an artist to generate and modify patterns in every surface easily. For this purpose a procedural pattern is appropriate. Procedural pattern is a pattern that can be generated automatically and controlled by a program. This chapter describes the research to develop a system to generate procedural pattern that resemble the patterns of Wayang Beber of Pacitan characters' textiles.

4.2 Related works

The programming approach of generating patterns or ornamentations has been explored for many years. Geng [43] has reviewed several researches on this field. He categorized the techniques into several approaches; two of them are closely related to this research. Those are layout-based creation of art patterns and art pattern creation by shape grammars.

One of the reliable methods is the layout-based creation of art pattern. This method generates an art pattern from a basic layout determined by user, and then in the process, the layout is modified into a desirable pattern [43]. Example of this method can be seen in a work by Hamekasi and Samavati [94]. Hamekasi and Samavati's work presents an analysis of Persian floral patterns based on circle packing. This approach separates the semantics and combinatory of the design from its geometry. It could generate new designs that have high level characteristics such as visual balance and imperfect symmetry.

The layout-based creation of pattern is an efficient method. Many types of art patterns have obvious structural characteristic. Layout-based creation of art pattern which use regular structures is convenient to be applied, however the resulting patterns often seem artificial.

Another approach is art pattern by shape grammars. Shape grammars are a set of mechanism for selecting and performing rules for shape computations. It gives the designers freedom to specify, explore, develop a design language in terms of the shape grammar, and select alternatives for desirable art patterns [43]. Application of this approach could be seen in a work by Wong, Zongker, and Salesin [95]. Their work presents a grammar-based approach to generate floral patterns using an adaptive clip art. They described adaptive clip art as a set of geometric primitives elements which is encoded as a set of rules. The pattern generation starts from user-specified seed points, and then the system will decide which element to grow. The Wong's system is automatic algorithmic system, in this system the artist has less control over the pattern. In this project, a semi-automatic system which allow artist to control some variation of the pattern detail is needed.

4.3. Features of Wayang Beber of Pacitan Characters' Cloth Pattern.

From the analysis of the reference image, typical features of Wayang Beber of Pacitan characters' textiles pattern are found. The pattern can be categorized into three types, those are:

1. Line pattern
2. Flower pattern
3. Vines pattern

The line pattern is the simplest one. It is a thin vertical line drawn repeatedly across the surface (see Figure 42). According to Sukir [23], this line pattern is called *cawi*. This feature is used to fill up a wide blank area in the picture to maintain a good visual balance.

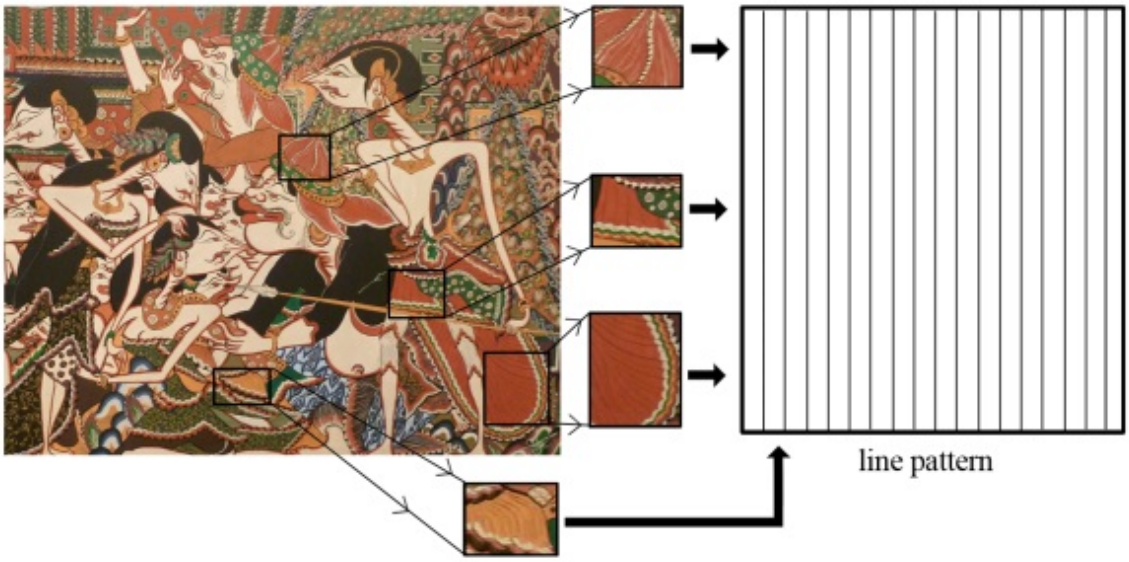


Figure 42. Line pattern on Wayang Beber of Pacitan's cloth

The other patterns are floral. There is no research which can be found to explain these patterns, so this study refers to another Indonesian traditional art called *batik*. *Batik* is a traditional technique to draw ornament on a textile. In the past, *batik* textile was worn by Javanese kings or nobilities. So it is plausible that the textiles depicted in Wayang Beber of Pacitan are *batik* textiles.

To verify this hypothesis the floral patterns on Wayang Beber of Pacitan are compared to the patterns of batik clothes. There are two floral patterns on Wayang Beber of Pacitan, those are the flower pattern, and the vines pattern. The flower pattern resembles a pattern of batik cloth called *ceplok*, and the vines pattern is identical with a pattern called *sulur-suluran* (see Figure 43). In this chapter these two kinds of batik pattern are examined.

The *ceplok* pattern has philosophical meaning of giving hope, wisdom, or guidance [96]. It is one of the oldest traditional patterns in Java, Indonesia. It can be seen in many sculptures from the ancient Buddha and Hindu era [97]. Therefore it is likely if this pattern is also found in Wayang Beber of Pacitan. *Ceplok* is classified as a geometrical pattern. This type of pattern is arranged geometrically. Particularly, *ceplok* pattern is arranged in a square shape (see Figure 44a). *Ceplok* has various motifs; one of them is called *truntum*. *Truntum* is a motif of a small flower, such as jasmine. This ornament often depicted with eight petals, but sometimes depicted with four or six petals, with various shape.

Sulur-suluran is also known as old motifs of batik. It is classified as a non-geometrical

pattern. This type of pattern has a free arrangement. In a batik cloth *sulur-suluran* pattern is made spread out and fill the entire surface. However, the vines pattern in Wayang Beber of Pacitan is simpler. It only grows in one direction, vertically or horizontally (see Figure 44b). This pattern consists of three part: main trunk, leaf, and flower.

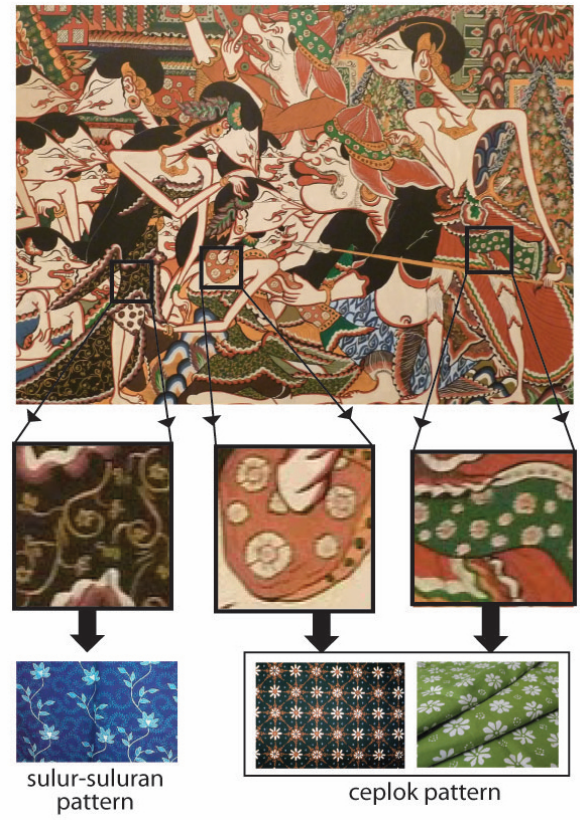
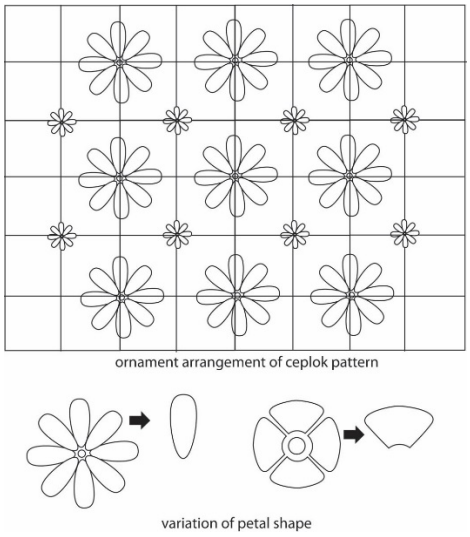
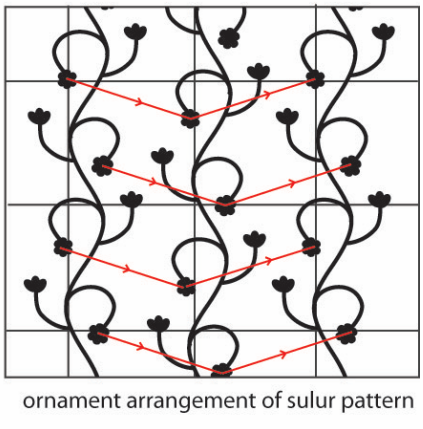


Figure 43. Comparison between the pattern of Wayang Beber of Pacitan's cloth and the pattern of batik clothes



(a)



(b)

Figure 44. (a).The composition of ceplok pattern. (b) sulur pattern on batik cloth

4.4. Developing the Procedural Pattern Shader

Since this system will be applied in 3DCG animation production, it should be able to generate patterns on a surface of 3DCG model. Therefore a shader is used in this system. The shader is created in Renderman interface. It generates patterns using s and t coloration process. The s and t coloration is a process for creating 2D texture on 3D model's surface by defining color position based on its coordinate in texture space. Texture space is two-dimensional, which is defined by two axis, *x* and *y*, or in this case can be referred as *s* and *t*. The coordinate of s and t both lie between 0.0 and 1.0. They represent a point location inside a dimensionless image of unit size.

Algorithm for the shader combines two pattern generation methods. Layout-based

approach and shape grammars approach. Wayang Beber of Pacitan patterns have regular structures which are convenient to be generated by the layout-based method. Details of the pattern can be controlled easily using the shape grammar approach. In this research, the shape grammar generation method is performed by adopting the Wong, Zongker, and Salesin's [95] pattern generation algorithm. The developed algorithm consists of two concepts: elements and rules. The elements correspond to the 2D geometric primitives that appear on the ornament, whereas the rules are certain procedures to arrange the elements.

The Elements

There are 6 basic elements defined in the algorithm which are used to compose Wayang Beber of Pacitan's cloth pattern (see Figure 45).

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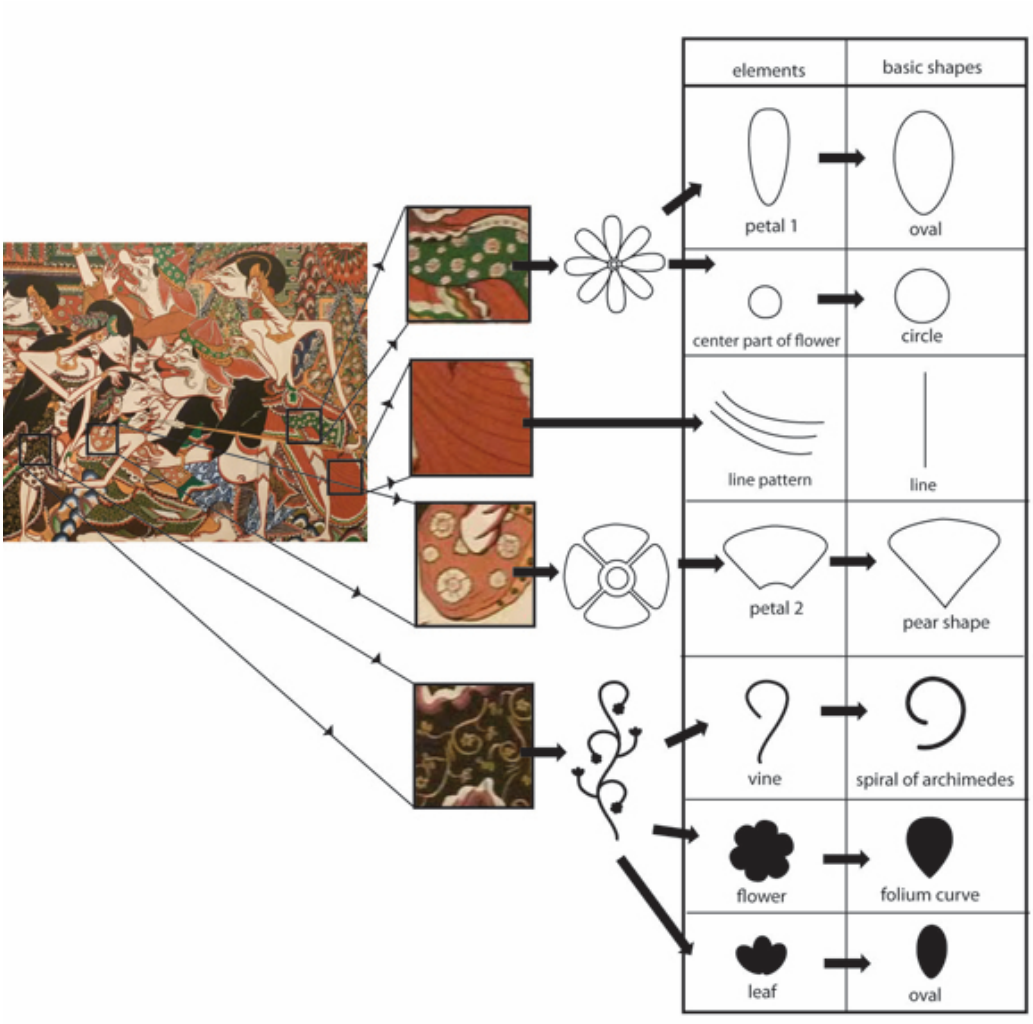

Figure 45. The elements of Wayang Beber of Pacitan's cloth pattern.

The first element is an oval, it is used to create petals of the flower pattern and leaves of the vines pattern. The second element is a circle; it is used to create the center part of the flower pattern. The third element is a thin line. It is used for the line pattern. The fourth element is a pear shape, it is used to create petal of the flower pattern. The fifth element is a spiral of Archimedes which is used to create trunks of the vines pattern. The sixth element is a folium curve, it is used to create flower petals of the vines pattern. Each element has attributes that are controlled by the rules.

The Rules

The rules are a conditional statement that should be met for doing the coloration process. The rules are divided into two:

1. The first rule is a condition for the iteration process. While this condition met, the iteration of coloration process will be continued.
2. The second rule is a condition that describes the coordinate of coloration area. The coloration process will be performed in the areas that meet this condition. The second rule determines which element is used. It is also determine position of the element on the texture space.

4.4.1 Generating Line Pattern

Rules to generate vertical line pattern is made based on Kendall Sor's ruled paper algorithm [98]. The first rule for line pattern is a procedure to repeat the coloration process. A new parameter is needed to define the color positions; it should be periodically repeated numbers. To obtain this parameter, the modulo operation is applied to the s and t values. The modulo operation finds the remainder of division of one number by another (see the following equation).

$$r_s = s - \left\lfloor \frac{s}{n} \right\rfloor \times n \quad (6)$$

$$r_t = t - \left\lfloor \frac{t}{n} \right\rfloor \times n \quad (7)$$

Where r_s is the remainder of s after the modulo operation is applied, $\left\lfloor \frac{s}{n} \right\rfloor$ is the largest integer less than or equal to $\frac{s}{n}$, n is the divisor, r_s is the remainder of t after the modulo operation is applied $\left\lfloor \frac{t}{n} \right\rfloor$ is the largest integer less than or equal to $\frac{t}{n}$.

To control the line width (thickness) a new variable w is added. It is defined using the

following equation:

$$w = \frac{n \times l}{10} \quad (8)$$

Where n is gap between the lines, and l is a value given by user to control the line width. The second rule is a conditional statement for coloration process. The coloration will be done if a following condition is met:

$$r_s < w \quad (9)$$

Where r_s is a remainder of s, it is used to repeat the coloration process, and w is a parameter to control the line width.

The result can be seen in Figure 46. A variation of line width was obtained by applying w value. It can be seen in Figure 47

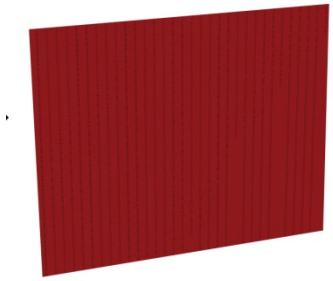

Figure 46. Generated line pattern

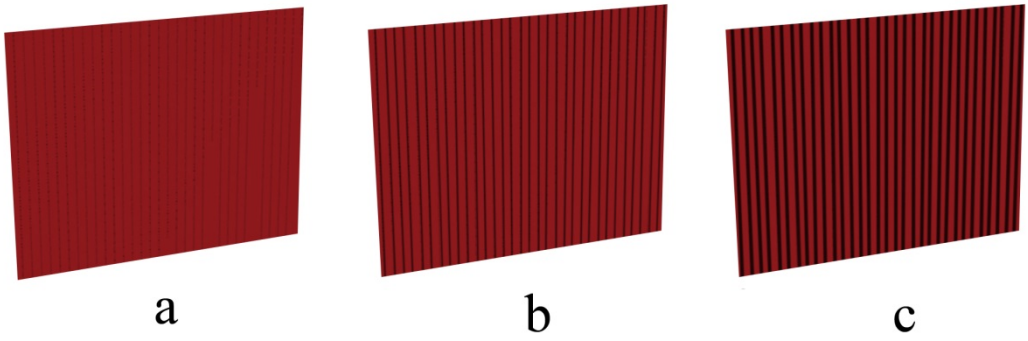

Figure 47. Variation of line width

4.4.2 Generating Flower Pattern

To generate a flower pattern, r_s and r_t are used as the coordinate of the coloration area, r_s is the result of modulo operation on s value, while rt is the result of modulo operation in t value. Both rs and r_t are repetitive numbers on vertical and horizontal axis. They

divide the surface into number of square modules (see Figure 48). The coloration is done in every module.

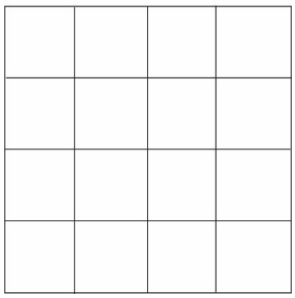

Figure 48. Flower pattern module

The coloration begins by applying the first rule. The first rule of flower pattern is a conditional statement for iteration of the petals coloration process. To create flower petals configuration, the coordinate of the coloration area is rotated gradually in each iteration. The rotation is done by applying following equation:

$$s_r = r_s \cos \alpha - r_t \sin \alpha \quad (10)$$

$$t_r = r_s \sin \alpha + r_t \cos \alpha \quad (11)$$

Where s_r is a new s coordinate of coloration position after rotation, t_r is a new t coordinate of the coloration position after the rotation, and α is the pattern rotation angle.
In every iteration α is recalculated, it is added by a value that given by user. The iteration is performed until the pattern rotation angle surpasses 360 degree (see Figure 49).
Then the second rule is applied. The second rule for the coloration is a conditional statement to controls the coloration area in texture space. The coloration will be done if the condition is met. To create the flower petal, a user can choose two shapes, those are an oval, and a pear-shaped quartic. The condition for an oval shape is:

$$s_r^2 + \mathbf{0.3}^{s_r} \times 2 \times t_r^2 <= z \quad (12)$$

Where s_r is a new s coordinate of the coloration position after the rotation, t_r is a new t coordinate of the coloration position after the rotation, and z is the petal size.
The condition for a pear-shape quartic is:

$$b \times \left(t_r \times \frac{c}{z} \right)^2 < \left(s_r \times \frac{c}{z} \right)^3 \times \left(a - \left(s_r \times \frac{c}{z} \right) \right) \quad (13)$$

Where a,b, and c are arbitrary real numbers.
Center of the flower is made by a circle. The condition for the circle is:

$$s_r^2 + t_r^2 < z \quad (14)$$

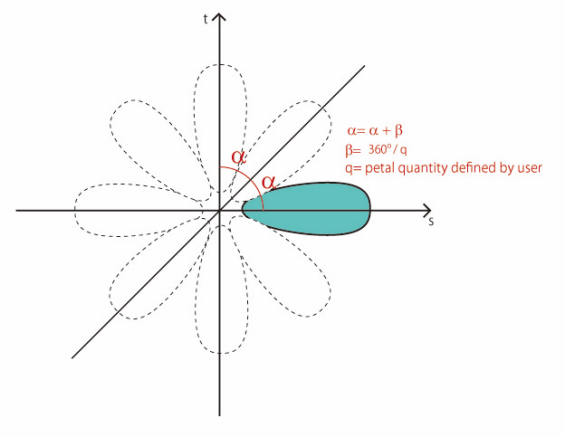

Figure 49. Iteration of flower pattern coloration

Some textiles have two types of flower patterns, a big flower and a small one. The size of the small flower is half of the big one. It is defined by:

$$z_s = \frac{z}{2} \tag{15}$$

The small flower petal can be made by an oval shape, the condition for the oval shape is:

$$s_r^2 + \mathbf{0.3}^{s_r} \times 2 \times t_t^2 <= z_s \tag{16}$$

It can also be made by a pear-shaped quartic, the condition for pear-shaped quartic is:

$$b \times \left(t_r \times \frac{c}{z_s} \right)^2 < \left(s_r \times \frac{c}{z_s} \right)^3 \times \left(a - \left(s_r \times \frac{c}{z_s} \right) \right) \tag{17}$$

The center of the small flower is made by a circle. The condition for the circle is:

$$s_r^2 + t_r^2 < z_s \tag{18}$$

The result can be seen in Figure 50.

Figure 50. Generated flower pattern

4.4.3 Generating Vines Pattern

To generate a vines pattern, r_s and t values are used as the coordinates of coloration area. r_s is the result of modulo operation on s value. It is repetitive numbers on horizontal axis. It divides the surface vertically into several modules (seeFigure 51). The coloration is done in every module.

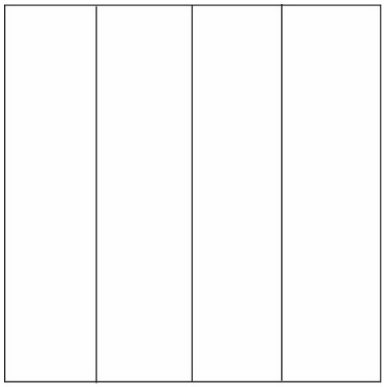

Figure 51. Vines pattern module

The vines pattern has two types of element that are subjected to different rules. The first type is vine, and the second type is flower and leaf.

The first rule for the vines is a condition for the iteration of the coloration process. This rule allows t value to be added by 0.4 in every iteration. The iteration is performed until the t value surpasses 1, this value is a limit of the surface's border.

The first rule for the flower and the leaf allows its coloration area to rotate gradually in every iteration. The rules are similar to the first rule of flower pattern, the iteration is performed until the pattern rotation angle surpasses 360 degree.

The second rule is a condition for the coloration process. The shape of the vine is created using a spiral of Archimedes. The condition for this shape is defined by:

$$s_{pos}1 < (R \times \theta) < s_{pos}2 \qquad (19)$$

Where s_{pos1} is the first s coordinate of the coloration area on the texture space, and s_{pos2} is the second s coordinate of the coloration area on the texture space. The s_{pos2} must be bigger than s_{pos1}, R is a radial coordinate of the spiral, and θ is an angular coordinate of the spiral.

The spiral of Archimedes is defined by a polar equation, therefore R and θ values must be calculated by converting the texture coordinates (s,t) to their polar equivalents. The conversion can be done by the following equations:

$$R = \sqrt{(\boldsymbol{r_s} - \mathbf{0.1})^2 + (\boldsymbol{t} - \mathbf{0.2})^2} \quad (20)$$

$$\theta = arctan\left(\frac{\boldsymbol{t}-\mathbf{0.2}}{\boldsymbol{r_s}-\mathbf{0.1}}\right) \quad (21)$$

Besides the trunks, the vines pattern also has flowers and leaves. The coloration for the flower will be done in a condition if:

$$((r_s \times z - s_{pos})^2 + (t \times z - t_{pos})^2) \times ((t \times z - t_{pos})^2 + (r_s \times z - s_{pos})$$
$$\times ((r_s \times z - s_{pos}) + b)) < 4a \times (r_s \times z - s_{pos}) \times (t \times z - t_{pos})^2 \quad (22)$$

Where r_s is the result of modulo operation on s value, s_{pos} is s coordinate of the coloration position, t_{pos} is t coordinate of the coloration position, z is the size, a, and b are arbitrary real numbers.

And the coloration for the leaf will be done in a condition if:

$$(r_s - s_{pos})^2 + (\mathbf{0.3}^{(r_s - s_{pos})} \times 2 \times (t - t_{pos})^2) <= z \quad (23)$$

The result can be seen in Figure 52.

Figure 52. Generated Vines Pattern

The algorithm also allows artists to control certain attributes of the pattern, such as pattern types, line width, petal types, petal size, petal quantity, vines sizes, and pattern color. The overall algorithm is summarized by the following pseudo code.

```
Input the type of pattern.
Apply modulo operation to s value using equation (6).
Apply modulo operation to t value using equation (7).
If type of pattern = “line”,
   Then, input color, input line width.
   Calculate line width (w) using equation (8).
   Calculate line coloration area using equation (9).
   Output color (result can be seen figure 46).
Else if type of pattern =” flower pattern”.
```

Then input how many petal types will use, 1 or 2.

Input petal shape, size, quantity (q), and input color.

Input second petal shape, quantity (q), and color if petal types = 2.

Declare the petal angle (α), $\alpha = 0$

Calculate the rotation angle (β), $\beta = 360 / q$

Calculate second petal size using equation (15)

Apply first rule of flower pattern's coloration.

While $\alpha \leq 360$

Calculate s value rotation using equation (10).

Calculate t value rotation using equation (11).

Apply second rule of flower pattern's coloration.

If petal shape = oval, then

Calculate coloration area using equation (12).

Else if petal shape = oval, then

Calculate coloration area using equation (13).

If petal types= 2, then

If second petal shape = oval, then

Calculate coloration area using equation (14).

Else if second petal shape = pear, then

Calculate coloration area using equation (15).

End if.

Output color.

If $\alpha > 360$, then break loop.

Recalculate α, $\alpha = \alpha + \beta$

Calculate center of first flower coloration area using equation (16).

Calculate center of second flower coloration area using equation (18) if petal types = 2.

Output color

(If petal types =1, result can be seen figure 54).

(If petal types =2, result can be seen figure 55).

Else if type of pattern =" vines pattern",

Then, input vine size and color.

Apply first rule of vines coloration.

While t ≤ 1

Calculate radial coordinate (R) using equation (20).

```
    Calculate angular coordinate (θ) using equation (21).
    Apply second rule of vines coloration.
    Calculate vine coloration area using equation (19).
    Output color.
    If t > 1, then break loop.
    Recalculate t, t=t +0.4
  Apply first rule of flower coloration.
  While α ≤ 360
    Calculate flower coloration area using equation (22).
    Output color.
    If α > 360,then break loop.
    Recalculate α, α=α+β
  Apply first rule of flower coloration.
  While α ≤ 180
    Calculate leaf coloration area using equation (23).
    Output color (result can be seen figure 56).
    If α > 360, then break loop.
    Recalculate α, α=α+β
```

4.5 Result and Evaluation

4.5.1 Rendering Experiments

The shader proposed in this chapter can produce three types of pattern; line pattern, flower pattern, and vines pattern. The flower pattern is arranged geometrically in square modules. It resembles a typical arrangement of a *ceplok* pattern composition. The vines pattern is arranged vertically, so that it resembles the arrangement of a *sulur* pattern.

This proposed shader allows artists to control certain parameters of the pattern. By using these parameters, the details of the pattern, such as petal shape, petal size, petals quantity, color, and arrangement can be easily modified. This shader's feature solves the problem in rendering many characters' textiles with certain variations of pattern. The comparison of rendering result using different pattern types can be seen in Figure 53.

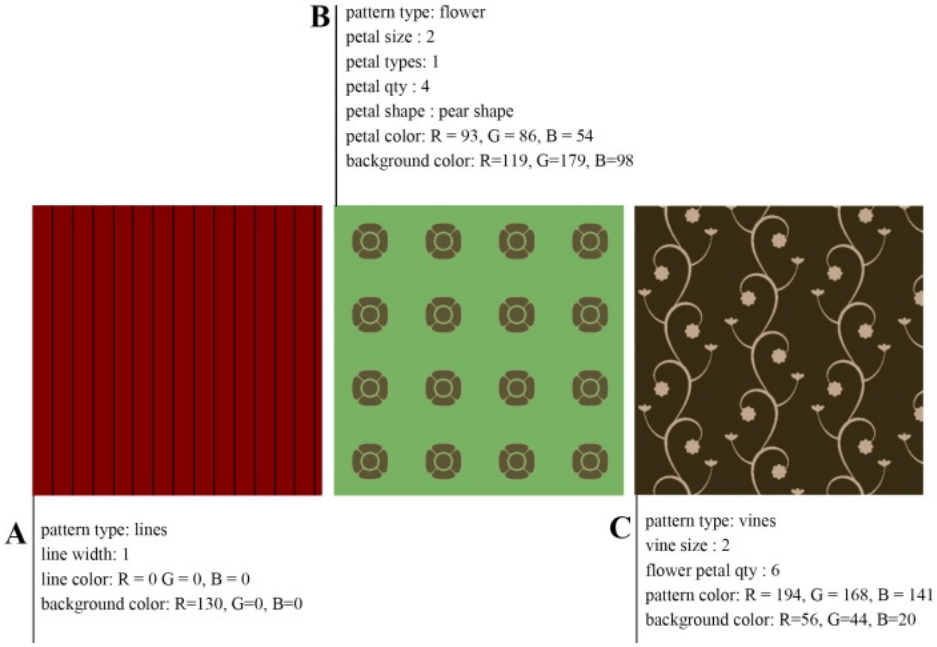

Figure 53. Comparison of rendering result using various pattern types and colors

Figure 53A was rendered using line pattern type, Figure 53B was rendered using flower pattern type, and Figure 53C was rendered using vines pattern type.
The comparison of flower pattern rendering result by using different petal quantity, shape, and color can be seen in Figure 54.

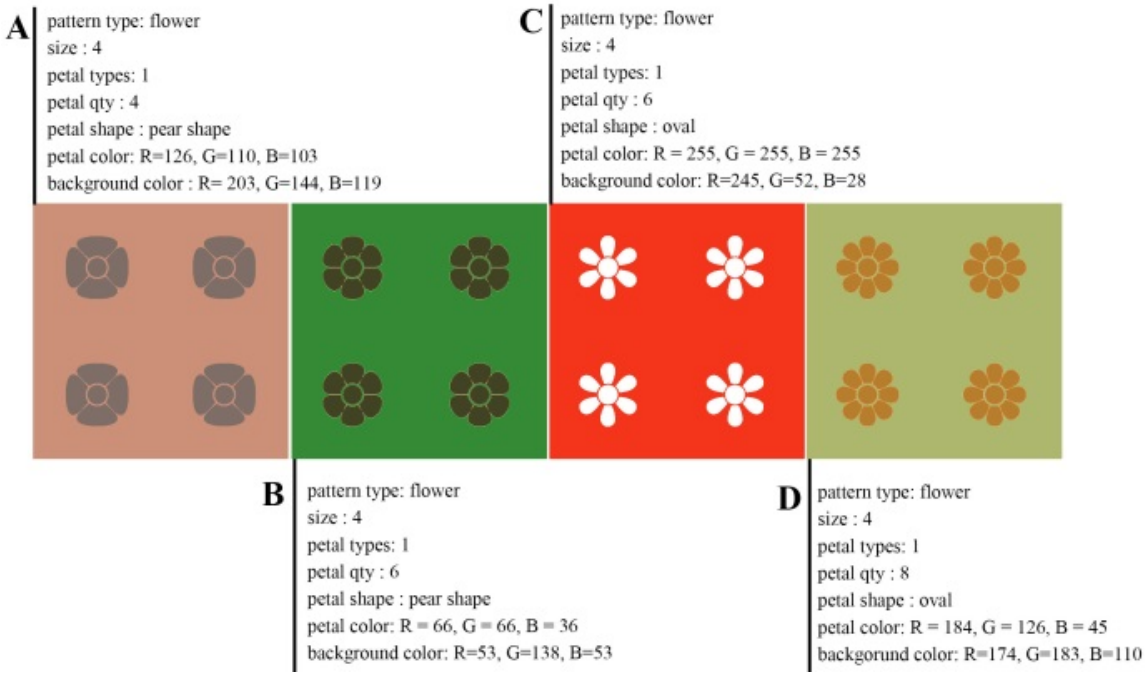

Figure 54. Comparison of flower pattern rendered using various petal shapes, quantities, and colors

Figure 54A and Figure 54B was rendered using a pear shape, Figure 54C and Figure 54D were rendered using an oval shape. Figure 54A was rendered using 4 petals, Figure 54B, and Figure 54C were rendered using 6 petals, and Figure 54D was rendered using 8 petals.

Using the proposed shader, a user can make a variation of flower arrangements by defining how many petal types which are used in the arrangement. User can choose whether 1 pattern type or 2 pattern types used in the arrangement. The comparison of flower pattern rendering result using different petal arrangement, and color can be seen in Figure 55.

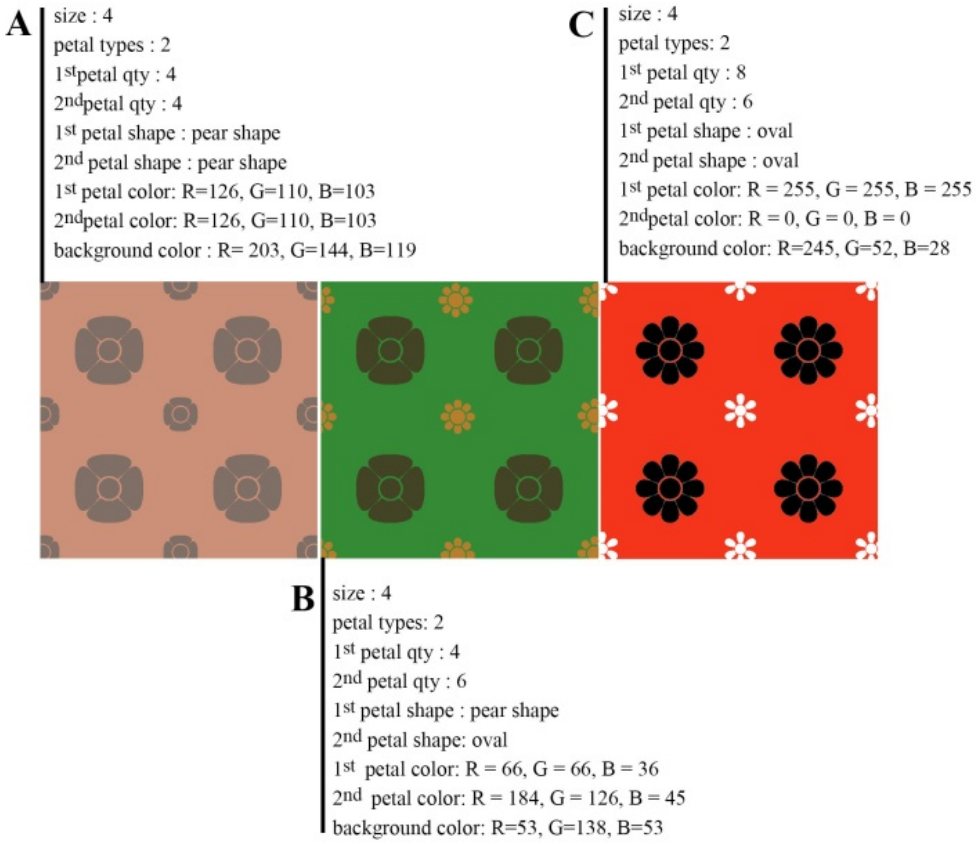

Figure 55. Comparison of rendering result using various pattern arrangements

Figure 55A shows a flower pattern arrangement rendered using two similar petal types, and quantity. While Figure 55B and Figure 55C show a flower arrangement rendered using two different petal types, and quantity.

The comparison of rendering result rendered using different pattern sizes can be seen in Figure 56.

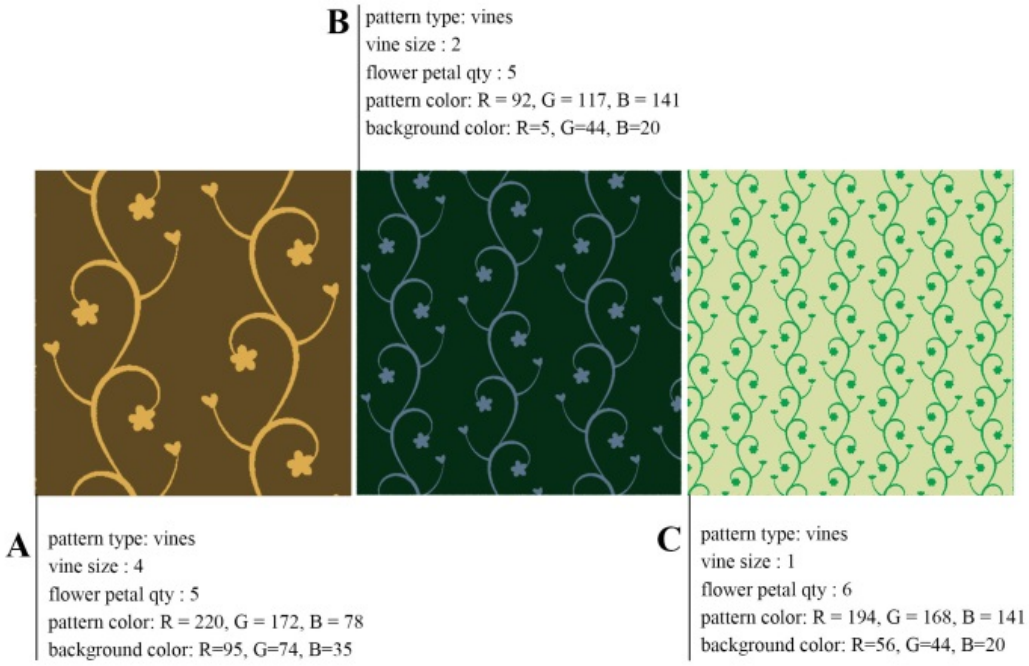

Figure 56. Comparison of vines pattern rendered using various pattern sizes, and colors.

Figure 56A shows a pattern rendered with size =4, Figure 56B show a pattern rendered with size = 2, while Figure 56Cshows a pattern rendered with size = 1.

4.5.2 Subjective Evaluation

There are eight rules which are used to evaluate the proposed shader:

To simulate a line pattern:

1. The shader should be able to generate a repetition of thin line.

To simulate flower pattern:

2. The shader should be able to generate a flower that has four and eight petals.
3. The shape of the generated petal should be able to resemble the shape of the petal on the reference image.
4. The shader also should be able to create two sizes of flower in a composition.
5. The shader also should be able to arrange the flower in a square formation.

To simulate vines pattern:

6. The shader should be able to generate trunks, leaves, and flowers of the vines.
7. The shape of the generated vines should be able to resemble the shape of the vines on the reference image.
8. The shader should be able to generate vines along a surface.

Result of the Subjective Evaluation

The proposed pattern shader is able to generate three types of patterns (see Figure

57). As shown in Figure 58, the proposed pattern shader is able to generate a repetition of thin lines. Figure 59a shows that the proposed pattern shader can generate 8 petals flower, Figure 59b shows that the proposed pattern shader can generate 4 petals flower. The shape of the generated petals is similar to the shape of the petals on the reference image. Figure 60 shows the ability of the proposed pattern shader to create two sizes of flower and arrange them in a square formation. As shown in Figure 61, the proposed shader is able to create trunks, flowers, and leaves of the vines pattern. The trunks, flowers, and leaves that were generated by the shader are quite similar to the reference image. As seen in Figure 62 that the proposed shader can arrange the vines pattern along a surface. However, there are differences between the generated pattern and the pattern on the reference image. On the reference image, the pattern seems more natural. Its element and layout are irregular. While the generated pattern seems artificial, its element and layout are uniform.
Overall, the proposed pattern shader is able to perform well in the reproduction of Wayang Beber of Pacitan painting (see Figure 63).

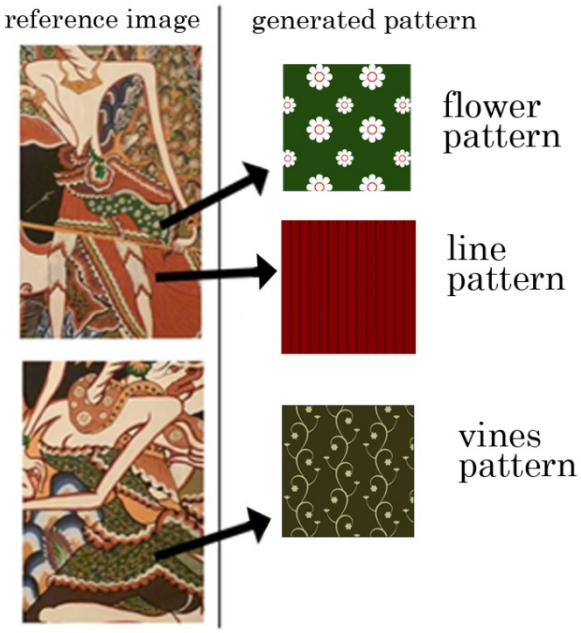

Figure 57. Comparison between the reference images and the generated patterns

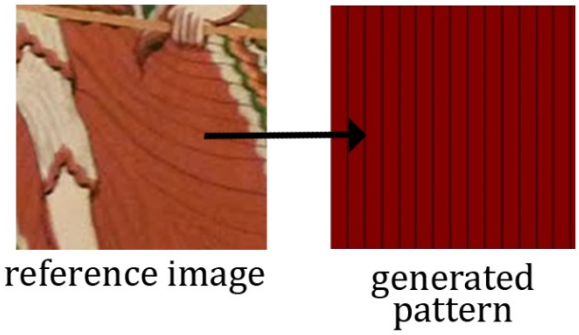

Figure 58. Comparison between the generated line pattern and the reference image

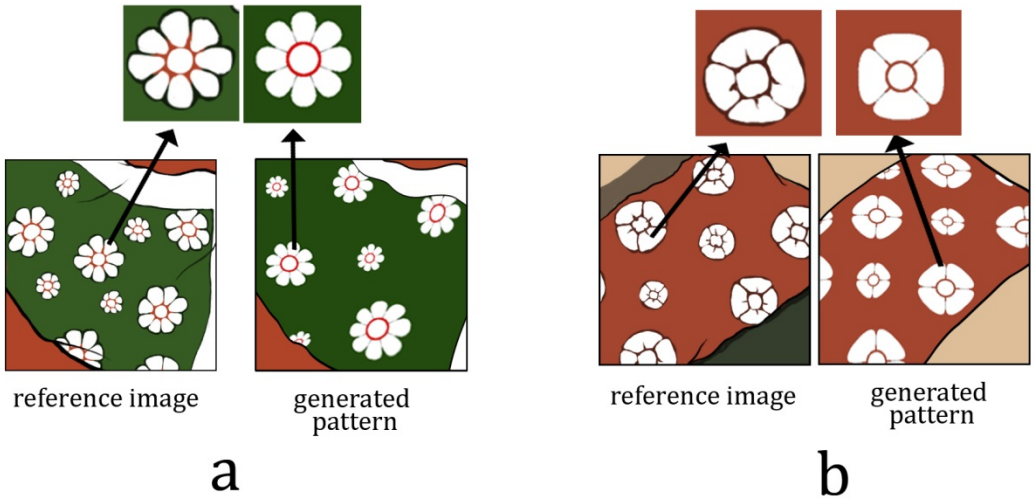

Figure 59. Comparison between the generated flower pattern and the reference image

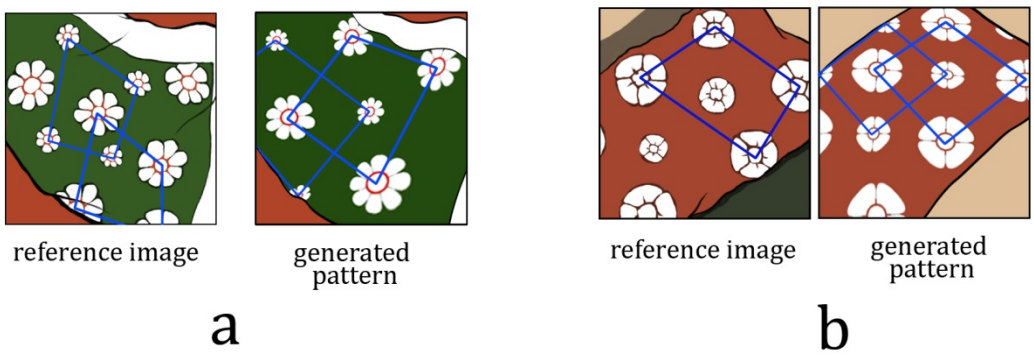

Figure 60. Comparison between the arrangement of the generated flower pattern and the reference image

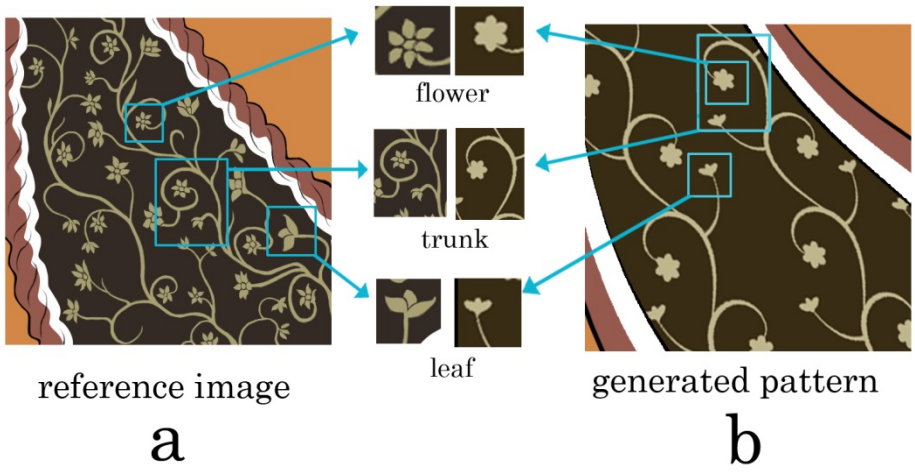

Figure 61. Comparison between the generated vines pattern and the reference image

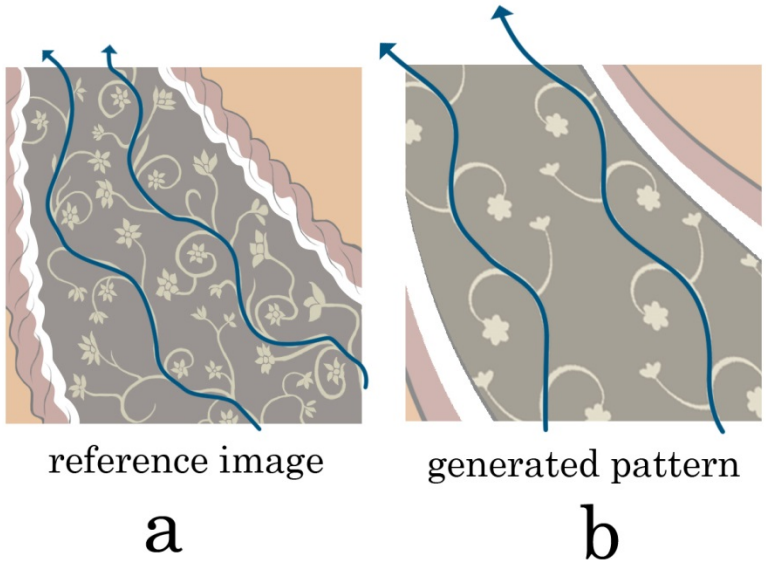

Figure 62. Comparison between the arrangement of the generated vines pattern and the reference image

Figure 63. Comparison of the reference image and the computer generated Wayang Beber of Pacitan scene

4.6. Concluding Remarks

This chapter describes development of a shader with a semi-automatic system to generate the flower pattern of Wayang Beber of Pacitan characters' textiles. Using this system, artists can control several parameters and modify the details of the pattern such as petal size, petal quantity, color, and arrangement.

The algorithm of this proposed shader adopts the adaptive clip art concept. This concept consists of two important things, the elements and the rules. The element is the basic shape that is used in a pattern arrangement. At this time our shader has 6 elements, these elements are sufficient to arrange the pattern of Wayang Beber of Pacitan's clothes. In the future, it is possible to add more elements into the shader to create more various

patterns.

The rules are certain procedures that are used to arrange the element. The proposed algorithm consists of two rules, the first rule is a condition to do an iteration of the coloration process, and the second rule is a condition to define the area of the coloration process.

There are some limitations of the proposed shader, such as:

1. The shader creates layout with a regular structure. It makes the arrangement of the generated pattern seems artificial.
2. The shader generates elements with uniform shapes. It is slightly different to the elements of patterns on the original painting which have irregular shapes. Irregularities are needed to create more artistic patterns.

Nevertheless, the proposed shader has the ability to generate a pattern such as one that could be found in Wayang Beber of Pacitan painting. For the preservation effort, it will be useful to reproduce pattern of Wayang Beber of Pacitan in 3DCG surfaces.

Chapter 5
Key Pose Extraction for Animating CG Character of Wayang Beber of Pacitan Painting

5.1 Overview

This chapter discusses technical issues for animating CG character of Wayang Beber of Pacitan. Character animation requires certain images called poses. As stated by Cavaliers [99] Pre-historic cave paintings and ancient sequential pictures (see Figure 64) can be considered as the origins of animation. These pictures have incorporated the concept of animation. Based on this argument, it can be inferred that character's poses can be obtained from traditional pictures such as Wayang Beber of Pacitan paintings. In this thesis two steps to obtain poses from the painting are proposed, those are extraction of key pose and interpolation of in-between frames. Explanations of these two proposed steps are described in the following chapters.

Figure 64. (a) Cave painting of Altamira[10] [100], (b) Relief on Borobudur temple, Indonesia[11] [101]

5.2. Key Poses in Animation

Key poses are needed to create a movement in animation. Atkinson [102] stated that in animation, a key pose is a term used to describe those critical position of an animated character or an object which depicts the extreme point in its path of motion, or accents in its expression or mood.

When planning a set of key poses for a shot or scene, an animator should consider several things, such as:

1. Requirements of the script and the particular actions that are required by the storyline.
2. Background layouts that will determine an acting space
3. Storyboard frames which indicate the relation of each shot with another.

Using key poses, an animator entirely control the way a character acts in every event as informed based on understanding of the character's personality, visual design and current emotional state.

Key poses are used to create key frames in an animation production. Key frames are series of drawings that determine physical actions of the character in animation [103].

5.3 Extracting Key Poses from Wayang Beber of Pacitan Painting

Atkinson's description shows that storyline is the major component in key poses creation. Therefore, to obtain key poses from of traditional pictures, an animator should understand the relation between the pictures and their storyline. An animator should know how to read the pictures. A theory that explains method to read pictures is the theory of visual language. There are many theories of visual language. Most of them try

[10] ©HTO

[11] ©Tropenmuseum

to elaborate a visual language as a system used in non-verbal communication media, particularly in modern time. For example, the theory proposed by Saint-Martin [104] describes a system of sign in the visual language which is used in non-verbal communication. Some theories focus on more specific field in media production, such as explained by Marriot and Meyer [105]. Marriot and Meyer elaborate theory of visual language in the relation to human-computer interaction. One theory that is found to be related to this research is proposed by Tabrani [83]. Tabrani explains theory of visual language which is particularly used to interpret Indonesian ancient and traditional pictures. He postulated his theory based on research on the Borneo cave painting, relief of Borobudur Temple, and Wayang Beber of Pacitan. Tabrani's theory of visual language is seen as a proper reference for this research.

5.3.1 Tabrani's Theory of Visual Language

As described by Tabrani [83], picture is a language system that has certain rules or grammar. There are two systems in the visual language: naturalistic-perspective-freeze moment system (NPF system) and space-time-plane system (STP system). The NPF system is a photorealistic depiction; it is usually used in a modern picture. This system represents one moment and one place in a picture. The STP system is a depiction that represents different times and different places in a picture. This system is usually used in a traditional picture.

The NPF and STP system has two types of grammar, namely inner grammar and outer grammar. Inner grammar is used in a single picture; it explains relation of images in the picture. Outer grammar is used in sequential pictures; it explains the relation between two juxtaposed pictures.

In an attempt to find key poses in a traditional picture, Tabrani's research on the relief of Borobudur temple [106] can be used as a reference. Borobudur is a Buddhist temple located in Central Java, Indonesia. It was built in the 9th century. In his research, Tabrani described the visual language of the relief on Borobudur temple.

Borobudur reliefs use space-time-plane system (STP). Borobudur reliefs consist of 1640 panels. In the panels, a figure is often depicted several times in several poses (see Figure 65). According to Tabrani, this is called multiple images depiction. Multiple images depiction is an inner grammar used to signify a movement in a certain period. For the purpose of this research, those multiple images can be used as a reference to create key poses. So basically, it can be inferred that the key poses can be extracted from the images in traditional pictures that are depicted using an inner grammar that signifies

movement. In visual language there are several types of inner grammars that signify movement, those are: multiple images, expressive line, additional line, distortion, and dynamic pose.

Figure 65. Multiple images depiction in Borobudur's panel[12] [107]

In multiple images grammar, a figure is drawn using several images to signify the movement (see Figure 66a). In expressive line grammar, figure is drawn using expressive outline to signify the movement (see Figure 66b). In additional line grammar, several lines are added outside the figure to signify movement (see Figure 66c). In distortion grammar that figure is depicted in distorted shape longer than its normal proportion to signify movement (see Figure 66d). In dynamic pose grammar, figure is depicted in a pose that has impression of motion (see Figure 66e). Key poses can be extracted from figures that are depicted with these grammars.

5.3.2. Visual Language of Wayang Beber of Pacitan painting

As stated before, key poses can be found by analyzing inner grammar of a picture. However, as explained by Atkinson, to obtain proper key poses, the whole structure of the picture should be understood in relation to the storyline. Therefore, the analysis of visual language in Wayang Beber of Pacitan painting is needed. The basic analysis has been done by Tabrani in 1991 [108]. He has elaborated the visual language system on Wayang Beber of Pacitan painting. Below, several grammars on Wayang Beber of Pacitan painting that are useful for key pose extraction are described. Basically, the grammar is used to identify the images that represent a movement in a Wayang Beber of Pacitan scene. These images are used as references for key pose extraction. The grammar is also used to determine the sequences of event in a scene that will be animated.

[12] ©Kinsbergen, Tropenmuseum

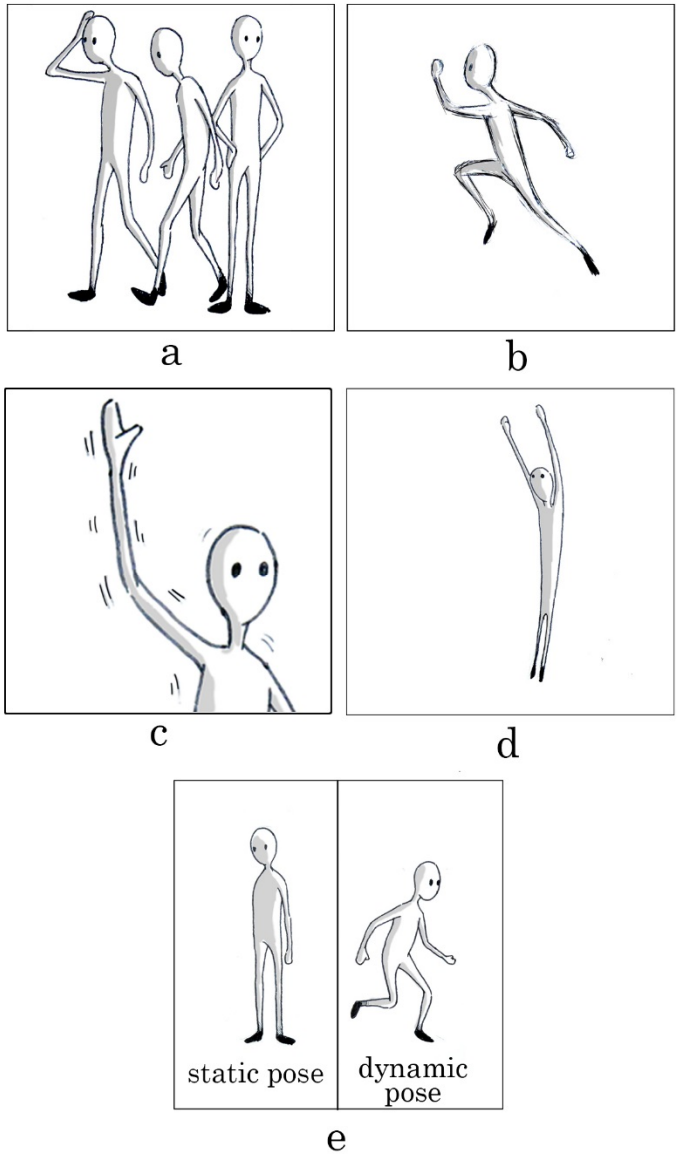

Figure 66. (a) Multiple images grammar, (b) Expressive line grammar, (c) Additional line grammar, (d) distortion grammar, (e) Dynamic pose grammar

Outer Grammar

In one scroll of Wayang Beber of Pacitan there are four juxtaposed scenes. According to its grammar, the scroll should be read from left to right (see Figure 67). This rule asserts position of a scene in the storyline.

The grammar also explains that each scene of Wayang Beber of Pacitan painting has different space and time; they do not have direct continuity. In modern visual language, it is similar to the scenes connected with dissolve transition where there are events in

certain times that are not told.

Figure 67. Outer grammar on Wayang Beber of Pacitan scroll

Inner Grammar

In a scene, usually there are several inner grammars used for different functions. The first grammar is used to create a focus of the scene. It clarifies characters that have an important role in the scene. In a Wayang Beber of Pacitan scene, the focus is placed in the middle of the composition. The important characters are placed in the center and always facing each other (see Figure 68). They are depicted relatively bigger than the others, and drawn entirely in a dynamic pose.

The second grammar is used to signify a movement. In a Wayang Beber of Pacitan scene, the movement is signified using a dynamic pose. Examples can be seen in Figure 69. In that scene there are four pairs of characters that have a dynamic pose. These images of the characters can be used as references for the key poses extraction.

The third grammar shows sequences of event in a scene. In a Wayang Beber of Pacitan scene there are multiple layers of pictures (see Figure 70). Each layer represents a different time. The story starts from the rear layer to the front. The front layer is the most important one; it depicts the climax event of the scene. Using this grammar, the timeline of the story in a particular scene that should be animated can be known

Figure 68. Inner grammar that shows important characters in a scene

Figure 69. Dynamic pose in Wayang Beber of Pacitan scene

.

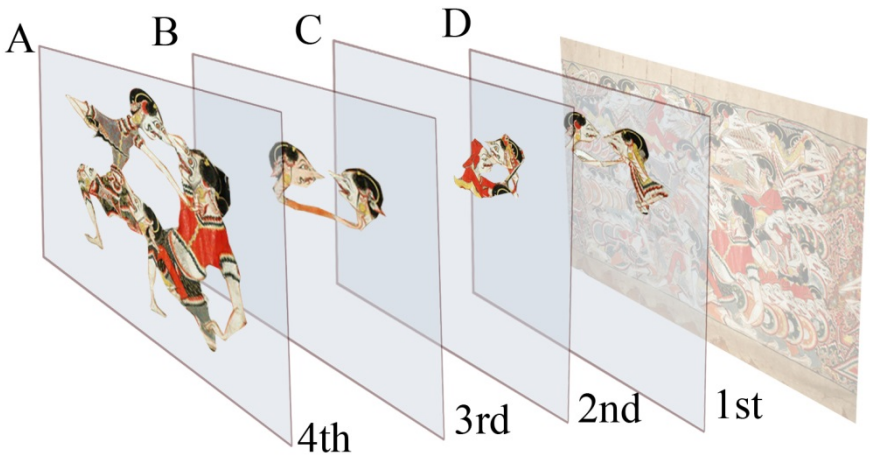

Figure 70. Multiple layers of time in Wayang Beber Pacitan scene

5.3.3 Extracting Key Pose of Wayang Beber of Pacitan Character

The third scene of the fifth scroll of Wayang Beber of Pacitan is used as a case study (See Figure 71). Based on analysis of the inner grammar; there are four layers of event in this scene (see Figure 70). Each layer contains two characters involved in the storyline. Each character is depicted using dynamic pose which can be extracted as key pose.

In this chapter, only key pose extraction from the front layer (4th layer in Figure 70) is described. There are two characters placed in the middle of the layer, facing each other. The characters have a dynamic pose. These poses are used as references for key poses extraction.

The extraction is done using Autodesk MAYA. The picture of Wayang Beber of Pacitan scene is imported as a reference image. Then, the key poses are extracted by posing a digital skeleton according to the dynamic pose of the characters in the reference image (See Figure 72).

Figure 71. Third scene of the fifth Wayang Beber of Pacitan scroll

Figure 72. Extracted Key poses

As a result, one key pose is obtained for each character. Each key pose is used as a key frame. To animate the character, more frames are needed. They are called in-between frames. The in-between frames have to be interpolated from the extraction result.

5.4. Interpolation of In-between Frames

In-between frames are made by interpolating frames from one key pose to the next key pose. In-between frames will determine details of the movement. To create a proper movement for Wayang characters, particular guidance is required for interpolation of in-between frames process. First thing to be considered, Wayang character does not represent a human figure [109], therefore its movement should not mimic the actual movement of a real human. This kind of movement cannot be understood by observing an actual movement of a human in the daily life. Reference for the movement should be

searched within the world of Wayang itself.

To understand Wayang character movement, in this chapter, three studies are performed, those are: the study on the work procedure of Wayang storyteller, the study of the movement of characters in Wayang Kulit (see Figure 73), and the study of the movement of characters in Wayang Orang. Wayang Kulit and Wayang Orang are two forms of Wayang that incorporate movement on their performance. Wayang Orang is a Wayang performance that performed by real people on a stage. In Wayang Orang performance, most of the movements are exaggerated with specific choreography (seeFigure 74). Results from this study are elaborated into principles of the movement of Wayang characters which will be used as guidance for animating Wayang Beber of Pacitan characters.

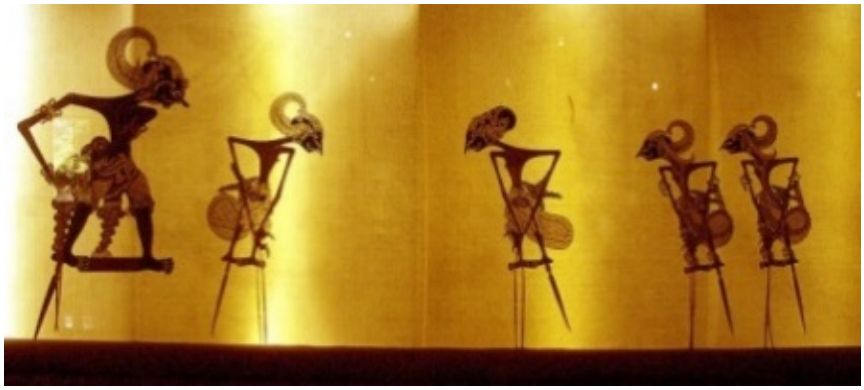

Figure 73. Wayang Kulit Puppets[13] [110]

Figure 74. Wayang Orang performance[14] [111]

[13] ©Kartapranata

[14] © Sekar Budaya Nusantara, TVRI

5.4.1. Understanding Wayang storyteller's work procedure

All Wayang performances, except Wayang Orang, are performed by a storyteller called *dalang*. The storyteller makes the character act and talk properly according to the story. He should know how to perform each character properly. Darmoko [112] described there are certain rules that should be followed by the storyteller. At first, the storyteller must understand the classification of Wayang characters.

The characters are classified by their roles, social status, and physical appearance. Each Wayang character in one class has a similar personality and attitude. After understand the classification, the storyteller will know how to perform the Wayang characters. There are particular principles to translate this personality and attitude into a talk and movement of the Wayang characters. Bassically, the principles are related to the speed and techniques for moving the puppet's arms and body. The principles only give a basic characteristic for the movement; moreover every storyteller can use his creativity to interpret the story and develop his own style of movement.

Based on the study , it can be concluded that the procedures of a Wayang storyteller works are:

1. A storyteller must understand the storyline.
2. A storyteller should understand the classification of Wayang character. Using this classification, he classifies the characters which are involved in a particular scene,
3. A storyteller should translates the movement of the characters based on the basic principles and his interpretation of the storyline.

5.4.2 The Movement of the characters in Wayang Kulit

Basically, the movement of Wayang Kulit puppet is made by combination of arms and whole figure movement (see Figure 75).

According to Roger Long [85], the movement is divided into three types. The first one is gesture. It is a basic movement of character while it stands in one place, including movement for talking and making salute. The second one is transition. It is the movement of a character from one place to other. It is including walking, running, and flying. The third one is battle movement. It is the movement of a character that is used in fighting scenes. It is including hitting, kicking, grabbing, and throwing.

In each type of movement, there are different qualities depending on a character's class. The differences are signified by variation of arm positions and speed of the movement.

Figure 75. (A) Arm movement of Wayang Kulit, (B) whole figure movement of Wayang Kulit

5.4.3 The Movement of the Characters in Wayang Orang

Wayang Orang is a later development of Wayang form. It was created after Wayang Kulit around the 18th century. Wayang Orang has more varied movements than Wayang Kulit. However it seems to imitate the movement of Wayang Kulit (see Figure 76). Similar to Wayang Kulit figure, Wayang Orang performer's body always faces the audience. The arm movement is also important features in Wayang Orang, it is supported by certain legs movement and body gestures (see Figure 77). In Wayang Orang, arms position, gaze, and stance are associated with specific personalities.

Figure 76. Comparison of Wayang Kulit and Wayang Orang

Figure 77. Movement in Wayang Orang performance[15] [113]

5.4.4 Movement Design Principles

There are three important points which are found in the studies. Firstly, as specified in the work procedure of Wayang storyteller, the movements of Wayang character should follow the character classification. Thus, it can be concluded that character classification is the most important determinant for the movement of Wayang characters.

Secondly, since the gestures and movements of Wayang Orang intend to imitate Wayang Kulit, the movements of Wayang Kulit can be used as the main reference for this research. There are two features of Wayang Kulit movement that can be deduced from the studies: the arm movement and gesture limitation.

Thirdly, Wayang Orang performers intend to imitate a Wayang Kulit puppet`s structure with their gesture (see Figure 78). This gesture creates a good silhouette pose. A good silhouette pose is a pose that can be seen clearly when it shown as a silhouette. Using this pose, performers' body shape can be recognized easily from a distance.

These findings can be elaborated into four principles of Wayang character's movement. The principles are:

a. Movements are determined by character's classes
b. Emphasis on arms movement.

[15] ©Sekar Budaya Nusantara, TVRI

c. Good silhouette pose.

d. Arms movement, gaze, and stance limitation.

Character Classification

Roger Long identified Wayang characters by their iconographic features and classified them based on their personalities. Referring to this, the characters in Wayang Beber of Pacitan can be divided into four classes, those are: refined character, gallant character, rude aggressive character, and funny character.

Emphasis on arms movement

This principle is derived from Wayang Kulit movement where the arm movement is the main feature. Arm movements are used to signify basic gesture movements such as talking (see Figure 79) or expressing emotion (see Figure 80).

Arms are also important in a walking movement. When a character is walking, usually the front arm is moving while the rear arm remains stationary. The position of the stationary arms signifies the character's personality. Low arm position is used to depict a refined personality (see Figure 81A), while high arm position is used to depict an aggressive personality (See Figure 81B).

Good Silhouette Pose

This principle is derived from a Wayang Kulit figure. It is also used in Wayang Orang. Basic gestures of Wayang Orang performer could be seen in Figure 82. To create a good silhouette pose, a Wayang figure's body should be positioned facing toward the audience and its head should be positioned facing aside toward another figure. Its hands should be put far from the body and its stance should be kept open while moving.

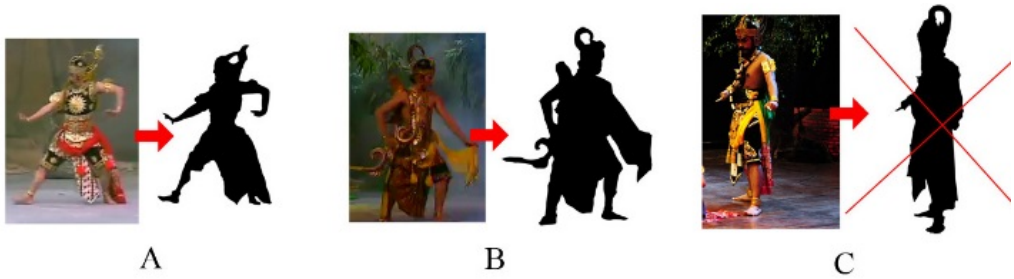

Figure 78. (A) and (B) Good silhouette pose in Wayang Orang, (C) Bad silhouette pose in Wayang Orang

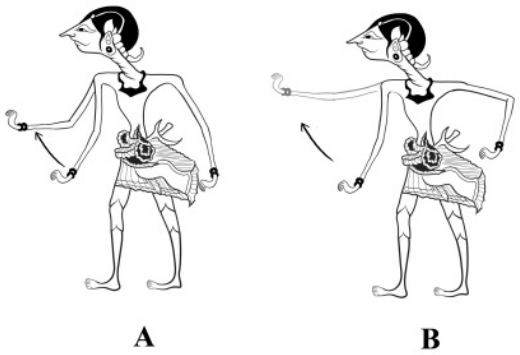

Figure 79. Arm movement to signify character talking, (A) Polite talking movement, (B) aggressive talking movement

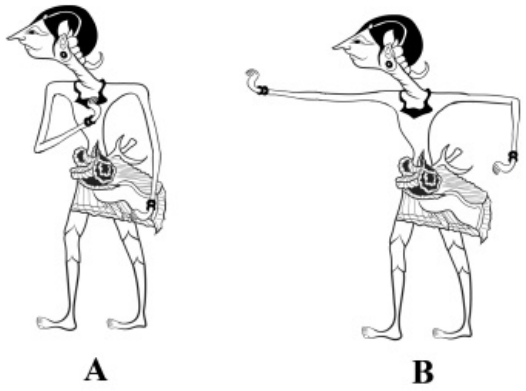

Figure 80. Arm movement to signify character expression, (A) sad expression, (B) angry expression

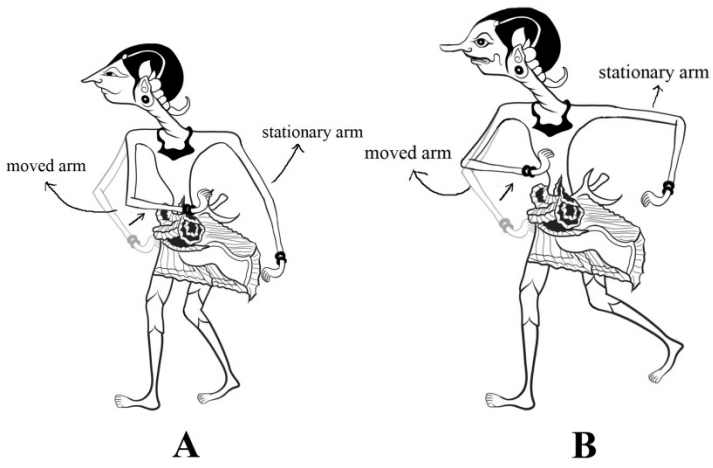

Figure 81. (A) Refined character walking, (B) gallant character walking

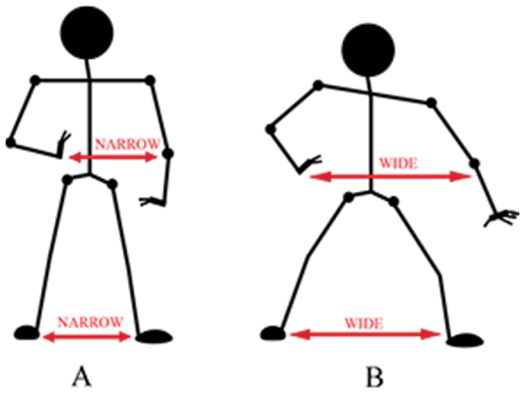

Figure 82. (A) Basic gesture of refined character in Wayang orang,

Arms Movement, Gaze, and Stance Limitation

Movements for the character in each class are made by following certain rules derived from Wayang Kulit movement. These rules are particularly applied for refined, gallant, and rude characters, while funny characters could be moved freely.

The first rule relates to arm movement. In Wayang Kulit, it is usually only the front arm of the figure which is moved, while the rear arm remains stationary. In some cases it can be the opposite. The position of stationary arm signifies the character's class (see Figure 83), the height of the arm's position is associated with aggressive qualities. Higher arm position means more aggressive character. In a talking movement, moved arm defines the character's class. The height of the arm movement for a refined character is usually between 0 to 30 degrees from its normal position (see Figure 83A), the height of arm movement for a gallant character is usually between 0 to 60 degrees from its normal position (see Figure 83B), and for a rude character is between 30 to 90 degrees from its normal position (see Figure 83C). However, in certain situations, this movement limitation can be ignored. For instance, when a refined character is angry, its arm can be moved up to 90 degrees from its normal position.

The second rule relates to the character's gaze or tilt of head. The head of a refined character should be always gazing down; the character head can be tilted between 45 to 60 degrees from its body (see Figure 84A). The head of a gallant can be tilted between 90 to 100 degrees from its body (see Figure 84B). The head of a rude character should be always gazing up; the character head can be tilted at least 100 degrees from its body (see Figure 84C).

The third rule relates to a character's stance. In Wayang Kulit there are two types of character stances: a narrow stance and a wide stance. A narrow stance signifies refined characters (see Figure 85A); while a wide stance signifies more aggressive characters

such as gallant and rude characters (see Figure 85B). In a Wayang Beber of Pacitan animation, the stance must be maintained at the same distance while the character is moving. The refined character's stance must be kept narrow, and gallant character stance must be kept wide.

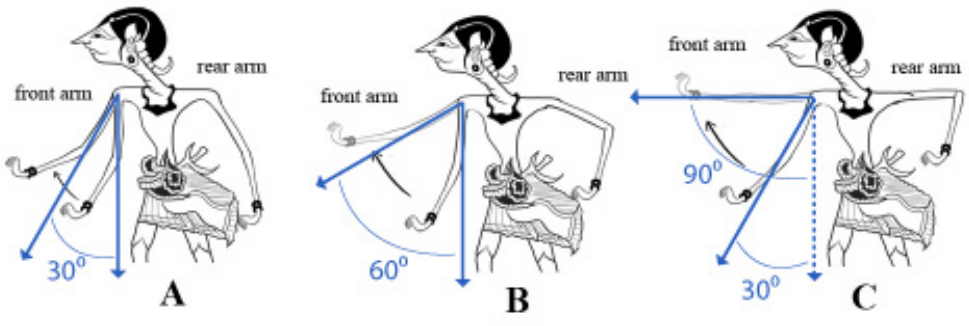

Figure 83. (A) Arm movement for a refined character (B) arm movement for a gallant character, (C) arm movement for a rude character

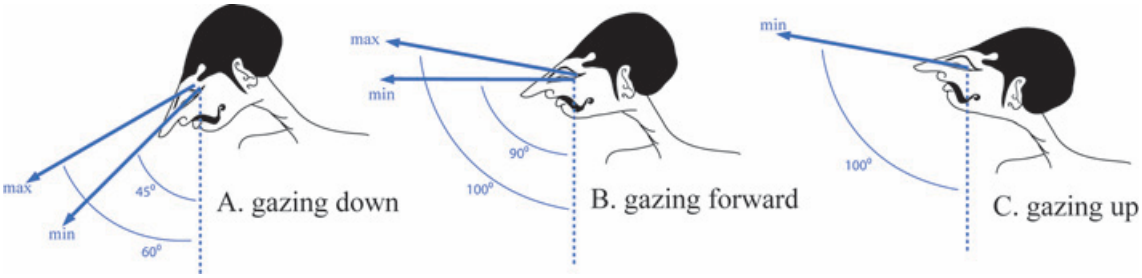

Figure 84. (A) Tilt limitation of a refined character head (B) Tilt limitation of a gallant character head, (c) Tilt limitation of a rude character head,

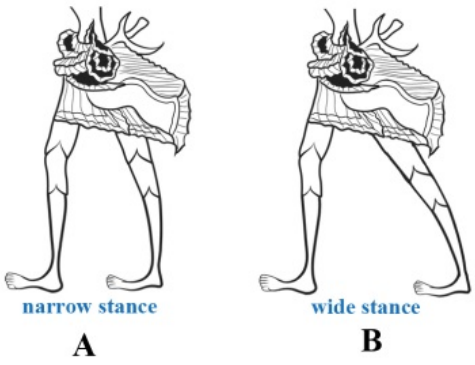

Figure 85. (A) Stance of a refined character (B) stance of a gallant and a rude character

5.4.5. Interpolation of In-between Frames of Wayang Beber of Pacitan Character

A Wayang Beber of Pacitan scene only provides one key pose of climax action for each character. In this paper, this is used as main key frame. Since an animation requires more than one key frame, frames interpolation is needed. The interpolation is done by adding frames after and before the main key frame.

Interpolation is performed by considering:

1. Storylines at the scenes those come before and after the particular scene.
2. Sequences of event on the layer in front and behind the particular layer.
3. Application of Wayang movement principles on each pose that is created.

The scene which is used as a sample (the third scene of the fifth scroll of Wayang Beber of Pacitan) depicts a battle. Event in this scene does not connect directly to its previous and next scenes. Yet, it has four layers of times. Main characters are laid on the front layer which is narrated last. It implies that when events on rear layers happen, two main characters have not been yet placed in the middle of the scene. According this depiction, the event can be interpreted as : two main characters come from the left and right sides of the scene. Then, they run to the middle of the scene and fight. At the end one of the characters is killed. In this research, a series of interpolated in-between frames are created in Autodesk MAYA to portray this event. Interpolated in-between frames can be seen in Figure 86.

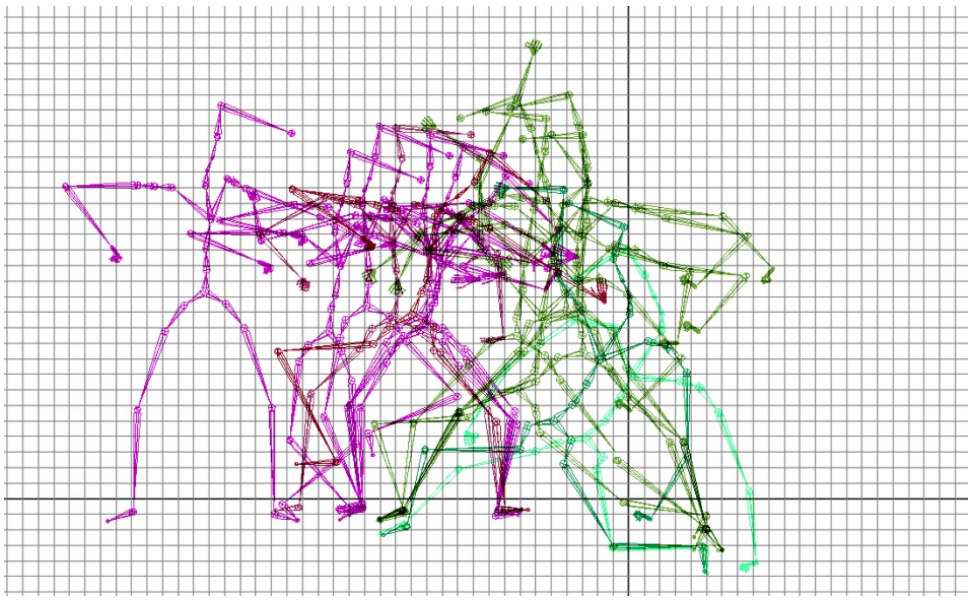

Figure 86. Interpolated in-between frames

The Wayang character movement principles are applied in every in-between frame. The

characters are classified as rude characters. Therefore, in each pose their elbow should be raised. Their stances are wide open and they gaze forward or upward. Their bodies always face toward the viewer and their arms are maintained far from the body to obtain a good silhouette. For more details, sequence of the in-between frames can be seen in Figure 87. The frame number 7 is the extracted key pose, while the others are interpolated in-between frames.

Using these extracted key poses and interpolated in-between frames, characters of Wayang Beber of Pacitan can be animated. Example of the animation frames can be seen in Figure 88. The animation is made using Autodesk MAYA, and rendered by PRman, a Renderman compliant renderer. For this animation, more in-between frames are added to obtain proper action for portraying the event.

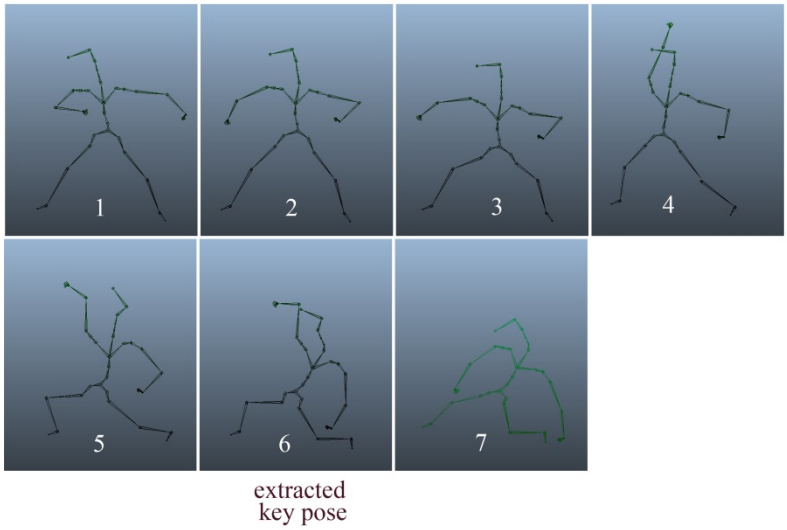

Figure 87. Sequence of interpolated in-between frames

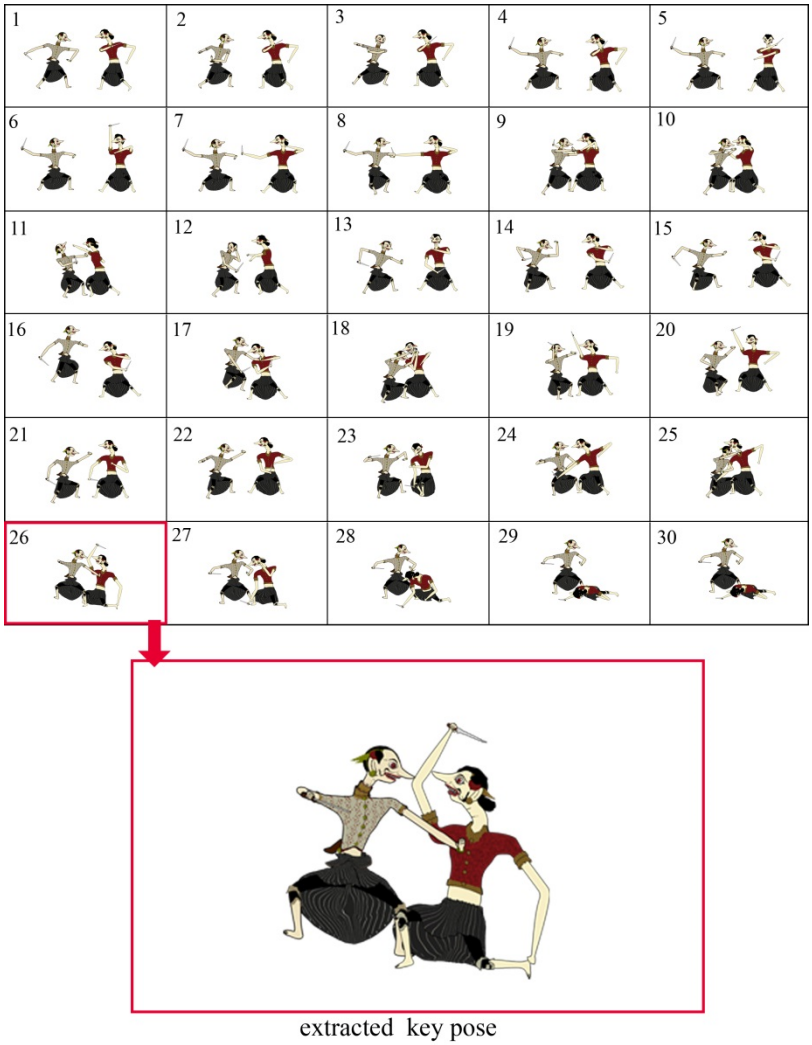

Figure 88. Frames of Character animation made using Autodesk MAYA

5.5 Evaluation

Evaluation of the proposed animation method was performed using user study. This study involves 135 users from Indonesia with the age between 15 to 35 years old. A sample of the animation was shown to users. Then, they were asked to assess the quality of the animation. 4 questions were given to the users in this evaluation.

1. **Question:**

   The users were asked whether they could get an impression of traditional movement from the animation.

   Result:

   70% of the users gave a positive response. They could get an impression of traditional movement from the animation (see Figure 89).

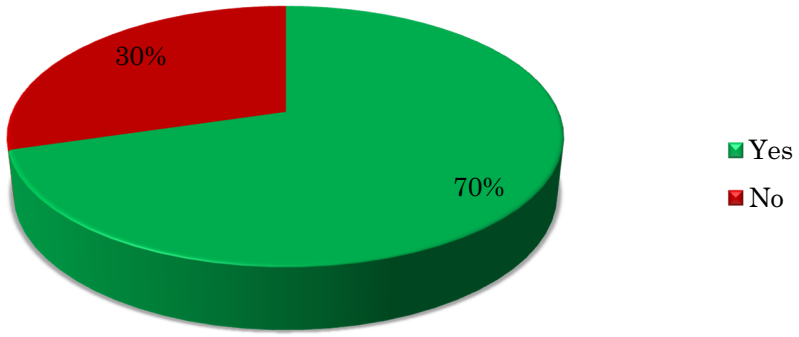

Figure 89. Users' response regarding the ability of the animation to give an impression of traditional movement

2. **Question:**

   The users were asked whether they would be interested if the animation sample is made into a film telling a Wayang story.

   Result:

   65% of the users gave a positive response. They would be interested if the animation sample is made into a film telling a Wayang story (see Figure 90).

   Average score: 3,8 (good)

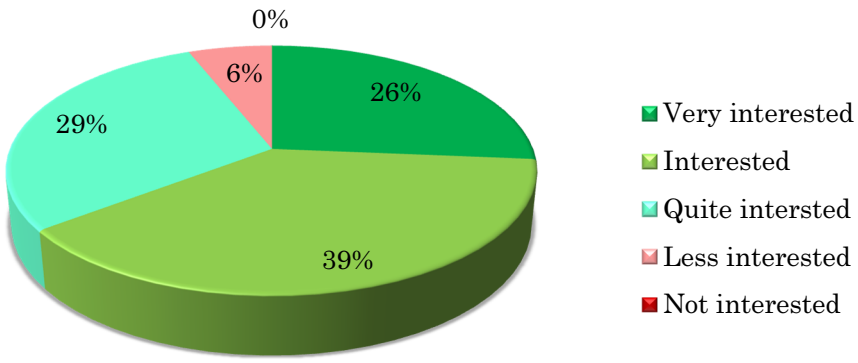

Figure 90. Users' response regarding their interest to an animated film made using the tehniques down in the animation sample

3. **Question:**

   After watching the animation sample, the users were asked if they agreed that the Wayang Beber of Pacitan is suitable to be applied in 3DCG animation.

   Result:

   81% of the users gave a positive response. They thought the visual style of Wayang Beber of Pacitan is suitable to be applied in 3DCG animation (see Figure 91).

   Average score: 4 (good)

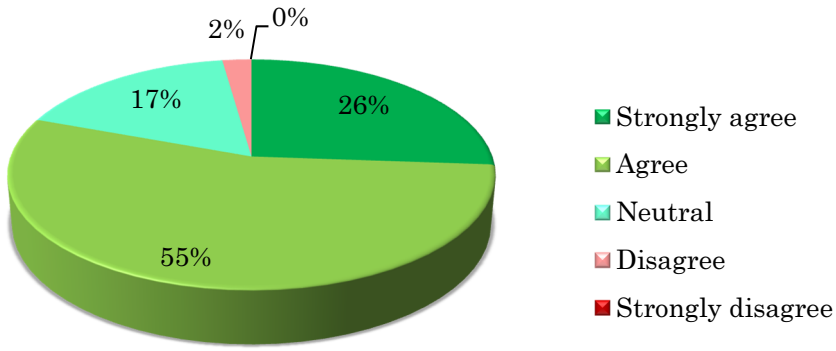

Figure 91. Users' response regarding suitability of Wayang Beber of Pacitan visual style if it is applied in 3CG animation

4. **Question:**

   After watching the animation sample, the users were asked if they agreed that the character design of Wayang Beber of Pacitan is suitable to be applied in 3DCG animation.

   Result:

   84% of the users gave a positive response. They thought the character design of Wayang Beber of Pacitan is suitable to be applied in 3DCG animation (see Figure 92).

   Average score: 4 (good)

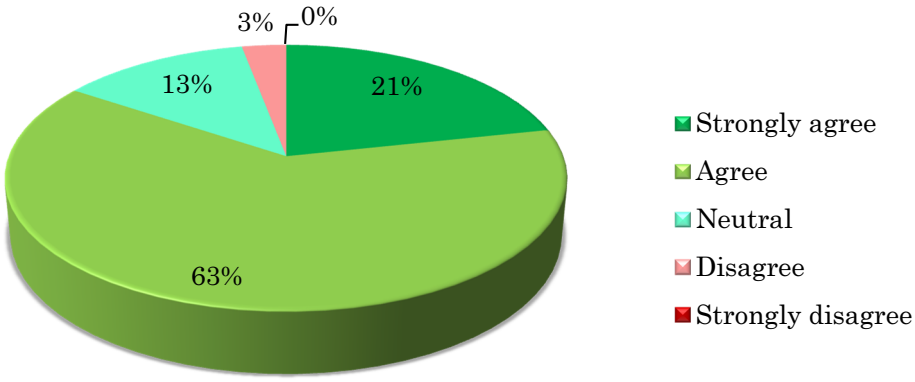

Figure 92. Users' response regarding suitability of Wayang Beber of Pacitan character design if it is applied in 3CG animation

Data Interpretation

- The result from the question number 1 shows that most of the users got an impression of a traditional movement when they are watching the animation sample. It indicates that the proposed method work properly to interpret the movement of Wayang characters.
- The result from question number2 shows that most of the users will be interested to see an animated film developing using the proposed techniques. It indicates that this project has good opportunity to be used to help Wayang Beber of Pacitan preservation effort.
- The results from question number 3 and number four show that the visual style and character design of Wayang Beber of Pacitan is suitable to be applied on 3DCG animation.

5.6 Concluding Remarks

Wayang Beber of Pacitan character figures have distinct distorted shapes and symbolic designs which require a specific approach to be animated. The animation can be done by obtaining key poses from the original Wayang Beber of Pacitan painting. This paper proposes two steps to do this.

First is the key pose extraction. The extraction is performed by searching representation of a character`s movement in the pictures. The visual language theory is used as tool for analysis. This step can obtain one main key pose for each character which is involved in the story. However the key pose cannot be extracted accurately. The character poses of the original Wayang Beber of Pacitan picture often create arbitrary, ignoring consistency of its figure's structure, sometimes it is difficult to trace with a 3D skeleton.

The in-between frames which are required for animating the character are obtained from the second step, i.e. interpolation of in-between frames. The interpolation is done by considering four Wayang movement principles.

The principles are derived from a study and analysis of Wayang art. The Wayang art in general has a unique way to represent a movement. It has strict rules and procedures regarding this matter. Basically the movement is inherited from Wayang Kulit performance. It is affected especially by the structures of two-dimensional Wayang Kulit puppets.

By performing the key pose extraction and the interpolation of in-between frames, required frames can be obtained for animating CG character of Wayang Beber of Pacitan painting.

Based on user study, it can be concluded that the proposed animation method is work properly. The study also shows that many Indonesian people will be interested to watch an animated film developed using the proposed methods. Therefore this project will be useful to help Wayang Beber of Pacitan preservation. People also see that the visual style and character design of Wayang Beber of Pacitan are suitable to be applied in a 3DCG. So, there is a good opportunity to develop Wayang Beber of Pacitan into a new work in the future.

Chapter 6
Conclusion and Recommendation

6.1 Conclusion

This thesis discusses an attempt to translate Wayang Beber of Pacitan painting into a 3DCG animation using non-photorealistic techniques. As planned, two types of research were done; the first type is art content research, the purpose is to document all information regarding visual style of Wayang Beber of Pacitan, and the second type is technical researches in which the purpose is to develop techniques needed for creating a CG animation based on Wayang Beber of Pacitan painting, such as: outline rendering, pattern generation, key pose extraction and in-between frames interpolation.

In this thesis the origin of the visual style of Wayang Beber of Pacitan was traced. Based on the study, it can be concluded that the style is derived from Wayang Batu of Panataran. There were many types of Wayang which existed before Wayang Batu of Panataran. However the distinctive stylized figure of Wayang began to be used in Wayang Batu of Panataran. Many scholars agreed that Wayang Batu of Panataran is the early reference for visual style of many types of Wayang which are known today.

The visual style changed greatly when the Islamic era began in Java. The style was

modified to accommodate Islamic rules that forbid a realistic depiction of living creatures. The modified visual style began to be used in Wayang Kulit Purwa. Then it was imitated in Wayang Beber of Pacitan. Because of the characteristics of its medium, the visual style of Wayang Beber of Pacitan has slight differences compared to that of Wayang Kulit Purwa. Although still following the Islamic rules, the figure has more realistic proportion.

This thesis also provides basic guidance to create visualization of Wayang Beber of Pacitan. It consists of two points:

1. How to design Wayang Beber of Pacitan character figure.

   A character design is usually made based on archetype, but a Wayang character is different. It is designed based on symbolism. This approach results in a different kind of character representations. All characters are divided into several classes. In each class the character has sort of similarities in their representation. In this thesis, this is called symbolic depiction.

   Another important point regarding the character design is that the figure is created by avoiding realistic depiction of human figure. It creates a specific feature called distorted proportion.

2. How to paint Wayang Beber of Pacitan painting.

   Wayang Beber of Pacitan is painted using a traditional painting technique called *sungging* which has strict procedures. It creates specific colors and patterns.

From the findings, it can be concluded that the aesthetic of Wayang Beber of Pacitan does not represent a real world rather than represent a set of ideas. Wayang Beber of Pacitan contains a set of symbols and grammars as visual language. It has such denotative and connotative meanings. The denotative meaning can be read using the grammar of the visual language. While to know further about the connotative meaning, one should understand the symbolism of Wayang characters and the philosophy of Wayang arts.

The second type of research in this thesis is technical research to find techniques for simulating Wayang Beber of Pacitan visual style and animating its character. In this thesis, two non-photorealistic techniques to render Wayang Beber of Pacitan visual style are proposed, those techniques are:

1. An outline rendering that uses an object-based silhouette rendering and a non-uniform point displacement algorithm. The image rendered using the proposed method still can be distinguished from the original painting. However based on the analysis, the problem lies on the 3DCG model, not on the rendering method. The proposed method

is able to simulate the outline of Wayang Beber of Pacitan figure properly.

2. A semi-automatic pattern generation based on shape grammar. This technique can simulate three patterns of Wayang Beber of Pacitan such as line, flower, and vines pattern. This approach has sort of limitation particularly in vines pattern creation. The generated pattern still seems artificial. Layout and elements of the patterns are too uniform. More irregularities are needed to create more desirable patterns.

In general, using these two techniques, simulating Wayang Beber of Pacitan visual style in 3DCG is feasible.

Another technical research in this thesis proposes a procedure to animate a Wayang Beber of Pacitan character. The procedure consists of two steps, the key pose extraction and the in-between frames interpolation. The key pose extraction basically relies on subjectivity of the animator to determine key pose based on scene analysis using grammar of the visual language. Yet, as described in chapter 5, there are some limitations from this approach. It is difficult to trace the arbitrary pose and proportion of 2D figure in the painting using the digital skeleton. In-between frames interpolation is performed by following four principles of the movement of Wayang characters which have been elaborated in the study.

The results obtained from the user study show positive feedbacks. Most of the users were interested to see application of the proposed animation method in a real animated film. They also stated that the proposed animation method is able to create the impression of traditional movement. It indicates that the method can work properly to translate the movement of Wayang characters.

Based on the results of the user study, it can be concluded that this 3DCG animation of Wayang Beber of Pacitan is a proper medium for supporting the preservation effort. It gives solution for the preservation problems. The animation will be interesting for young generation of viewers. It will be useful for introducing Wayang Beber of Pacitan to young generations.

With the use of proposed methods, 3DCG is able to simulate Wayang Beber of Pacitan visual style. Using 3DCG animation story can be delivered without the presence of storyteller. It will help people to understand the story of Wayang Beber of Pacitan. As mentioned before, the story is an important aspect of Wayang Beber of Pacitan. It embodies valuable knowledge and knowledge for community. By incorporating this visual style in animation, the story will not lose its artistic connection with its roots and relevance.

The 3DCG as digital archive has durability, and is easy to be duplicated. It is also easy

to be disseminated; it can be shown in broadcast television or in on-line website. Therefore it will provide an access for public to see Wayang Beber of Pacitan. By utilizing these media, hopefully Wayang Beber of Pacitan can be preserved for the merit of the future generation.

6.2 Recommendation

6.2.1 Optimizing the Methods

The following are recommendations of future work which can be performed by current author or other researchers to optimize the methods for simulating Wayang Beber of Pacitan in 3DCG:

1. Research on view-dependent modelling method for creating 3DCG character of Wayang Beber of Pacitan.

   It is difficult for multiple views depiction of Wayang Beber of Pacitan figure to be resembled using the regular 3D modelling approach. For instance, in some figures, the eyes are almost always depicted from the front view even though the head is drawn from the side. Research on a view-dependent modelling method [114] can be performed to solve this problem.

2. Research to incorporate growth algorithm in pattern generation.

   The vines pattern generated in this thesis seems rigid, straight, and unnatural. As can be seen on batik textiles, a vines pattern is able to bend and spread in any direction. A research to incorporate growth algorithm in pattern generation can be conducted to achieve more desirable vines pattern.

3. Research to create decorative trees of Wayang Beber of Pacitan painting in 3DCG

   This thesis focuses on the creation of the 3DCG Wayang Beber of Pacitan character figure. The other parts of Wayang Beber of Pacitan painting such as decorative tress on the background have not been explored further. A fully decorative background is one of distinctive characteristics of Wayang Beber of Pacitan painting. Therefore a research to create such trees can be conducted.

6.2.2 Next Steps for the Preservation Efforts

Nevertheless, this research is just a beginning of an effort to preserve Wayang Beber of Pacitan. This research proposes a strategy and methods to create digital preservation of Wayang Beber of Pacitan using a 3DCG technology. It only focuses on the documentation and representation in the digital preservation. The next step

that is dissemination needs to be planned.

Moreover, the real application of the research in this thesis cannot be done without involvement of other stakeholders such as academics, cultural institutions, and government in Indonesia. There are feasible steps can be done as the follow-up of this research:

1. For further development, the research can be brought to the Art Faculty in Bandung Institute of Technology. The Art Faculty in Bandung Institute of Technology is one of academic institutions that have concern in preserving Indonesia traditional art.
2. The result of this research can be proposed to the Wayang Museum in Jakarta for real implementation. The animation can be used as a visual aid to show Wayang Beber story in the museum.
3. The result of this research can be proposed to the Ministry of Culture and Education of Republic Indonesia to get support for further implementation.

6.2.3 Future Works on Wayang Arts

There are many researches related to Wayang arts which can be conducted in the future. As mentioned before, there are various types of Wayang. Each of them has unique characteristics. Many of them have not been studied thoroughly. Some types of Wayang have been neglected and need to be revived.

The researches of Wayang arts can be focused in various aspects such as history, philosophy, culture, visual art, or future of the Wayang arts. The history of Wayang arts is still interesting to be studied. The research in this thesis studied the transformation of Wayang Beber. It focused on the history of Wayang arts in pre-colonial era. Many types of Wayang have been created since that era. Historical study of Wayang arts in colonial and post-colonial era can be conducted in the future.

Another research that can be conducted is related to the future of Wayang arts. Wayang can be considered as early visual media. As shown in this research, many interesting values studied from Wayang can be applied in modern media. For example, as shown by the results of the user study, the visual style and character design of Wayang Beber of Pacitan is suitable to be applied in 3DCG animation. An alternative method for designing a character also can be developed based on the study on Wayang characters. As mentioned before, Wayang characters are designed based on symbolism. By incorporating symbolism, a distinct representation of the character can be created.

The result of this thesis also shows that the traditional visual style of Wayang can be simulated using a 3DCG. The movement of Wayang characters is possible to be translated into an animation. So, there is a possibility to develop a new creative work based on this method in the future.

Researches on new works combining the traditional values of Wayang arts and digital media can be explored further in the future. It will open possibilities for the creation of new types of Wayang.

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List of Publication

*Publication related to this thesis

Peer Reviewed Journal

1. B. Grahita, T. Komma, “Identification of Character Figure Visual Style in Wayang Beber of Pacitan Painting”, *International Journal of ADADA*, Vol 18, No. 3, pp 40-47, 2014
2. B. Grahita, T. Komma, K. Kushiyama, “Shader Based Generated Ornamentation for Rendering Wayang Beber of Pacitan Character's Cloth Pattern”, *Journal of Society of Art and Science*, Vol.13, No.3,177-184, 2014
3. B. Grahita, T. Komma, K. Kushiyama, “Generating Wayang Beber of Pacitan Character’s Outline Using Renderman Interface”, *International Journal of ADADA*, Vol 17, No. 2, pp 68-75, 2013

International Conference Proceeding

1. B. Grahita, T. Komma, “DEVELOPING NON-PHOTOREALISTIC ANIMATION TECHNIQUES FOR PRESERVING THE VISUAL STYLE OF WAYANG BEBER OF PACITAN”, The 10th Asian Forum on Graphic Science, pp.33-34, 4-7 August 2015, Bangkok, Thailand.
2. B. Grahita, T. Komma, “Designing An Exaggerated Movement of The Character For Wayang Beber of Pacitan CG Animation Production”, International Workshop on Image Electronic and Visual Computing 2014, pp.259-264, 7-10 October 2014, Ko-Samui, Thailand.
3. B. Grahita, T. Komma, “Procedural Flower Pattern for Developing CG Animation of Wayang Beber of Pacitan”, International Conference of ADADA 2013, pp.8-11, 13-14 December 2013, Seoul, South Korea.
4. B. Grahita, T. Komma, K. Kushiyama, “CG Programming Approach to Generate Pattern of Wayang Beber Pacitan Character’s Cloth”, International Conference

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2. B. Grahita, T. Komma, K. Kushiyama, “Visual Analysis of Wayang Beber Pacitan Character Figure”, JSGS autumn conference 2012, pp.71-74, Tokyo, Japan.