3D POINT CLOUD FACE RECONSTRUCTION FROM 2D IMAGE USING PIXEL DENSITY TECHNIQUE

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ABSTRACT

3D face reconstruction has been broadly studied and used in many fields. The aim of this project is to construct a three dimensional (3D) point cloud face from two dimensional (2D) images. When a 2D image is uploaded into the system, Face detection function detects the face from the 2D image. Then, the Linear Pixel Shuffling technique is used to extract the pixel from the image. After that, the depth data is calculated. In this system, GUI menu is used so that users can interact with the system. There are other alternative choices to allow the user to capture a new photo instead using the only default photo. The basic transformation like, rotation, cell size and scale is called in the GUI menu. There are three experiments conducted to test the accuracy of the 3D model. The first test is the brightness test. During the test, three same images but varying in the level of brightness is used to compare the differences in the 3D reconstruction of the face. Through this experiment, sufficient amounts of brightness such as < 40%, 40%-60% and > 60% are needed to get an accurate result. The cell size test is carried out in the second experiment. In this test, as the cell size exceeds 6, the accuracy of the 3D model becomes lower. Furthermore, the shape of the 3D model will become cubic-look and unclear. Lastly, the memory test is examined to check the efficiency of the system. The memory consumption is low, 30-60 MB because there are not much complicated algorithm present in the system. In the future work, the 3D face model not only can be done by reconstructing the 3D face but also other objects. Besides, a more realistic 3D face model can be constructed instead of only construct in point cloud form.

PEMBINAAN SEMULA TITK AWAN MUKA TIGA DIMENSI (3D) DARIPADA IMEJ 2D MENGGUNAKAN TEKNIK KETUMPATAN PIXEL

ABSTRAK

Pembinaan semula muka tiga dimensi (3D) telah dikaji secara meluasnya dan juga digunakan dalam pelbagai bidang. Projek ini bermatlamat untuk membina sekeping gambar 3D titik awan dari gambar dua dimensi (2D). Pengesanan muka ini berlaku apabila imej 2D telah dikesan dalam sistem tersebut. Kemudian, teknik Linear Pixel Shuffling akan digunakan untuk mengekstrak pixel dari imej. Data kedalaman seterusnya akan dikira. Dalam sistem ini, menu GUI bertindak sebagai medium interaksi antara pengguna dengan sistem. Penggunaan alternatif yang lain adalah dengan menggunakan penangkapan gambar baru selain daripada mengguna imej yang dipilih terdahulu. Selepas itu, menu diciptakan bagi memudahkan pengguna untuk berinteraksi denganya. Transformasi asas seperti putaran, saiz sel serta skala telah diiktiraf dalam menu tersebut. Terdapat tiga eksperimen untuk menguji ketepatan model 3D. Ujian pertama adalah ujian kecerahan. Dalam proses ujian ini, terdapat tiga imej yang hanya berbeza dalam tahap kecerahannya iaitu < 40%, 40%-60% serta > 60% yang telah digunakan untuk membandingkan perbezaan outputnya. Melalui eksperimen ini, kecerahan yang optimum amat diperlukan untuk mendapatkan keputusan yang paling tepat. Ujian saiz sel pula telah dijalankan semasa eksperimen kedua. Dalam ujian ini, apabila saiz sel melebihi 6, ketepatan model 3D menjadi lebih rendah. Tambahan pula, bentuk model 3D akan menjadi "cubic-look" dan tidak jelas. Ujian memori juga telah diperiksa bagi menguji kecekapan sistem. Penggunaan memori dalam sistem ini adalah rendah, 30-60 MB disebabkan oleh algoritma yang tidak rumit. Bagi meluaskan projek ini pada masa yang akan datang, model muka 3D dapat memodelkan muka dan objek-objek lain. Model muka 3D juga dapat dibina dengan lebih realistik selain daripada bentuk yang bertitik awan.

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CHAPTER 1

INTRODUCTION

1.1 Overview

Three-dimensional (3D) face reconstruction is broadly applied in virtual reality and video gaming. It currently draws a lot of attention in the areas of Computer Vision and Computer Graphic communities because of the realism of the objects. Most of the video game series such as FIFA Football, which is a series of an association football video game consisting of their own virtual characters. Besides, it is important for the massive multiplayer online games (MMOGs) to recognise their own characters. However, such game has yet to achieve the creation of the exact face replica to represent the player as there is no high-level representation of the 3D world (Mohan, 2011). Therefore, the idea of this final year project begins with the study of reconstructing 3D point cloud face reconstruction from two-dimensional (2D) image by using the pixel density technique which improves face reconstruction as well as face recognition.

Point cloud is a set of multidimensional points which depends on the external surface of a 3D object (Johnson, 1999). So, point cloud is a set of ordinary points without any exact ordering or connection where the points are represented by the x, y, and z coordinates. In three-dimensional space, each point from every channel contains different data such as lighting, area and occlusion. Apart from that, point cloud is crucial to represent geometric objects or samplings. The geometry objects or samplings will be plotted out from thousands of tiny points. The higher number of points that are being plotted will create more realistic object. Figure 1.1 shows the example of the point cloud models of certain geometry objects. A point cloud object can easily be obtained by using scanner (Liang & Zhao, 2013). In addition, point cloud can also be applied in the medical field where it can be represented as the volumetric data for medical imaging. Point cloud can be used in product design and quality guarantee in industry field.

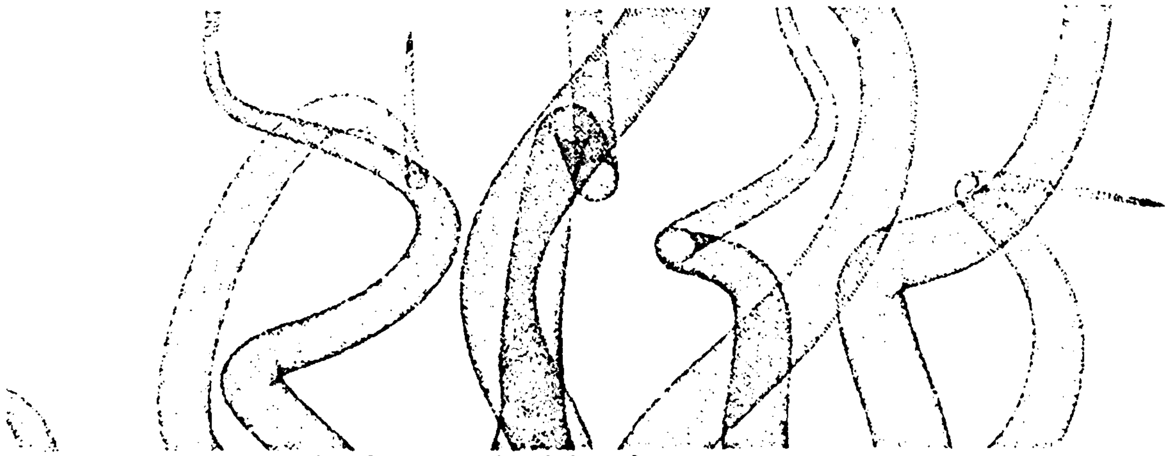

Figure 1.1 An example of a point cloud data (source: http://renderman.pixar.com/view/point-clouds)

The 3D point cloud face is plotted from 2D image by point attributes including surface normal and local point densities which are usually computed in a prepossessing step (Richter & Dollner, 2013). In another words, the aim of this project is to apply pixel density in determining 3D point cloud from the 2D image.

Pixel, originated from the words Picture Element (PEL) is defined as any of the small individual areas on the computer screen, which together forms the whole display. In other words, pixels are the smallest unit of information or small points in graphic image where they combine together to form a whole picture (Miranda, 2009). Each of the location of the pixel is represented to the coordinate. Each pixel consists of 3 bytes of their own specific RGB colour. The distances between the pixels produce a full image. Pixel density refers to the actual measurement of pixels on the screen surface of a device and also known as the resolution of the device.

This final year project will focus on reconstructing 3D point cloud face instead of constructing a 3D face model. There are several techniques that are used for reconstructing 3D model from the 2D image where they depend on the intensity of colours and the image's depth. Depth or coordinate *z* is important in the process of constructing a 3D model.

In this study, a normal 2D camera will be used to capture a 2D face image which then leads to obtaining of pixel density from the image. Next, depth data and RGB data will be collected to plot the 3D point cloud face and the position of the user face will be determined by the RGB data and depth data. Throughout this study, a prototype of a 3D point cloud face can be reconstructed as more points are plotted.

1.2 Problem Background

Modelling of 3D face is a worthwhile technology in several applications such as movie character generation and face recognition. There are several methods that can be used to construct a 3D model. One of the methods to reconstruct the head model is B-splines method. According to Zhang and Molenbroek (2004), the B-spline method has been an effective technique and it is highly recommended to be reconstructed separately for complex surfaces. However, there is limitation on plotting out the points. The reason is that the method has been focusing on laser scanning and there will be hidden points which are difficult to be plotted out. Therefore, the formed object will be deformed from the original image. Non-uniform rational B-splines (NURBS) method was also implemented in constructing 3D model. According to Luximon *et al.* (2011), non-uniform rational B-splines (NURMS) is not appropriate to be applied in statistical analysis as the accuracy for the model is not stated specifically and it is comparatively complex.

A technique is proposed in reconstructing depth from image appearance to its depth by using example mappings. The idea of this method is to collect the database from depth appearance of each object. Then, the depth of the object will be estimated by matching up the depth from each similar object. Although, this method has its benefits in estimating the depth of the back image, but it needs to undergo a wider range of circumference (Hassner & Basri, 2006).

Shape from Shading (SFS) method is another way by using the reflected light intensity to obtain the depth. The shadow that appears on the surface gives the depth information (Zhang *et al.*, 1999). The light source position from the reflection of the object and the refraction of the object will therefore give the point coordinates. Zhang *et al.* (1999) stated that the depth, z coordinate can be determined either by the distance from the camera to the surface point or the surface height to x-y plane. However, the result shows that the algorithms produce a poor real time image and the data does not give precise predictions on the real data.

In order to achieve a prototype of a 3D point cloud face from 2D image, a face reconstruction method according to the pixel density is suggested. Previous suggested method, View-dependent Pixel Coloring (VDPC) was introduced by Yang (2003). The main concept of this method is to use the texture-mapping function to change the input image to a desired view point. As a consequence to the output image, a programmable pixel rendering function is used to construct a decision colour consistence in order to assign to each of the pixels.

Lastly, a rigid point set registration or non-rigid point set registration is used to register the point set. Iterative Closest Point (ICP) algorithm is one of the methods for the point set registration. Many studies have used this method to determine the matching points. Still, ICP needs the two point sets to be close and this method may not be obtainable when the transformation is non-rigid. (Myronenko *et al.*, 2006).

Despite of using ICP, Myronenko *et al.* (2006) has presented a method known as Coherent Point Drift (CPD) and this method has been improved by Wang *et al.*, (2011). According to Wang *et al.* (2011), the registration performance of the original CPD method is poor. This is because the weight parameter in this method is needed to set up manually. Meanwhile, Myronenko *et al.* (2006) realised that when in large in-plane rotation, this method also could not function perfectly. Hence, the extended CPD algorithm is then proposed by implementing the combination of hybrid optimization scheme algorithm and the Nelder-Mead simplex method.

1.3 Problem Statement

This final year project reflects on the reconstruction of 3D point cloud face based on pixel density. In order to plot out the point cloud data without using any 3D devices, an appropriate method to obtain the depth data and colour intensity are needed. Although there are several methods to obtain the data, there is no method that can achieve 100 percent guarantee on the accuracy of the depth (coordinate *z*). Besides, pixels are also needed to be located. There are a few methods to be applied but it only can be applied in certain situation.

1.4 Aim

The aim of this project is to construct three-dimensional (3D) point cloud face from the two- dimensional (2D) image.

1.5 Objective

The objectives of this final year project are:-

i. To enhance pixel density differences in 2D image using colour intensity and depth
ii. To reconstruct 3D point cloud face model from the enhanced pixel density differences
iii. To develop a prototype of 3D point cloud face model

1.6 Scope and Limitation

The scopes of this final year project are as follows:

a) To compute the depth data obtained from the colour density of each pixel of the 2D image.
b) Reconstruct 3D point cloud face model from 2D image.
c) Set the resolution of the 2D image as 320 x 400 pixels. So that the image to shows will be equalize and the window of the system is fixed.
d) The reconstruction of the 3D model is only mainly focus on the human face. As this system is only reconstruct human face.
e) 3D devices such as 3D camera (Kinect) are not applied in this final year project.
f) Not more than two 2D images will be used as depth comparison.

1.7 Justification

The development of 3D face reconstruction is widely used in many fields in this age. Generally, instead of reconstructing 2D face image into 3D face model, this project will transform 3D objects into 3D point cloud face model. This is because point cloud is made based on the surface of the image.

A simple brightness depth formula is chosen as the method to obtain the depth data according to the brightness. As a result, a programmable pixel rendering function is used to make a decision in assigning colour consistency to each of the pixels. However this method could not achieve 100 percent guarantee on its depth accuracy (coordinate z).

1.8 Report Organization

In this section, the summary for every chapter in this final year project will be explained briefly.

In Chapter 1, the importance of 3D face reconstruction will be explained and definitions of point cloud, and pixel are justified as well as the concept of the reconstruction. Then, the problem background and problem statement will be reviewed followed by aim, objectives, scope and limitations of this project.

In Chapter 2, the topics on 3D face reconstruction from 2D image and application of 3D face reconstruction will be discussed. After history, different types of techniques used in determining the depth data and technique in registering the point set will be elaborated.

In Chapter 3, the methodology of this final year project will be listed and the outline of this project will be designed. Lastly, the procedure of this final year project will be further elaborated.

In Chapter 4, the system design of the entire system will be introduced. The Unified Modeling Language (UML) diagram will be constructed to introduce the entire system. This chapter also shows class diagram, sequence diagram and input output diagram in detail.

In Chapter 5, the techniques that are used to reconstruct 3D face have been briefly discussed and the mathematical solution of the system will be analysed. Besides, several experiments will be conducted to test the performance of the system as well as the accuracy of the 3D model.

In Chapter 6, the full summary of the system will be discussed. Then, the contribution of this project will also be discussed and also the future work.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, 3D face reconstruction will be briefly explained. Then, the application on 3D face reconstruction in different field will be further discussed. Pixel density, which is classified into the intensity of colour and image depth will be added into the discussion. Technique works in SFS to obtain the depth data from a 2D image will be further explained. Next, Example Mapping and View-Dependent Pixel Coloring (VDPC) will be reviewed. The point set registration is divided into two parts. Iterative Closet Point (ICP) Algorithm and Coherent Point Drift (CPD) Algorithm and these will be briefly discussed as well. Lastly, the information discussed in this whole chapter will be summarized.

2.2 3D Face Reconstruction

During Palaeolithic or the Old Stone Age in the earliest era of human development, most of the art were drawn in cave. The World History ASFMS Social Studies explained that, Palaeolithic people created the art to represent important events such as rituals or ceremonies. As the time goes by, the concept of art had changed. According to Science Daily (2010), art are drawn not only to represent important events but many other scenarios such as scenery view and human face. These art are known as the two-dimensional art. In the past or the present, people use 2D art to represent an individual. For example, to search information from the communities on a missing person, a picture of the missing individual is drawn and posted everywhere.

Today, 3D face reconstruction has drawn many attention in the areas of Computer Vision and Computer Graphic communities. 3D face reconstruction plays a more important role compared to 2D images in computer graphics. This is because 2D images could not provide information that is 3D images. 2D images only carry the texture information but not depth information (Zhuang *et al.*, 2006). Face is important for every single being. This is because it gives identity to an individual. A person will be recognized not only through their physical appearance but also by their face. This phenomena does not only happen in real life but also in virtual life. For example, a player needs to create their own character without face replica for games in massive multiplayer online games (MMOGs). The faces in the game help players to recognize their own character. Therefore, plenty of researches on 3D face reconstruction were done.

There are several techniques that were discovered to reconstruct 3D face. The first method is reconstructing the 3D face using a single or multiple views (Choi *et al.*, 2010). This method is started with retrieving facial poses. Then, facial landmark is set by detecting two anchor points. Based on these initial steps, the process is then divided into two: single view and multiple views. To obtain a single view of the input for building a 3-dimensional face, warping procedure is applied using a generic 3D face model. Meanwhile, the 3-dimensional landmark is needed for the reconstruction of multiple views by applying sparse bundle adjustment.

Besides, the 3D face can be reconstructed from a small set of feature points. This method mainly obtains information from the texture and 2D shapes of faces. Then, a database containing small amount of features points which are the best matched position of the shapes and texture will be retrieved. The 3D face will then be reconstructed according to the database. This method not only minimized the face deformation but also reconstruct the 3D face similar to the original 2D image.

face model of a particular individual, but it can act as a stimulus for recollection of a missing person (Evison, 1996). The reconstruction of a 3D face will not only reveals the identity of the being but also expose and preserve the intangible heritage. For example, a male skull was discovered under Leicester car park early 2013. A news from the Guardian (Kennedy, 2013) reported that the male skull had complete its reconstruction and the result had verified that the skull belongs to a long lost Plantagenet King, Richard III (Figure 2.2).

Figure 2.2 Face reconstruction of the last Plantagenet King, Richard III (Kennedy, 2013)

Furthermore, 3D face reconstruction currently is an active area in video gaming industry. Now, games in current generation allow real life actors to be fully immersed into the near real life game. For instance, a new era of sports game, FIFA Football recreate an environment that allows players to experience a living stadium. Apart from that, it allows the player to create their own teams and assign formations and tactics to the character. According to EA Sports team, it contains a technology which allows the player to upload photo of their own face and this can be loaded into the game. The character in the games is created based on the real life football player. In the realm of technology, FIFA 14 had produced a realistic face texture compared to the previous versions. Figure 2.3 below shows that the real life character in FIFA 14.

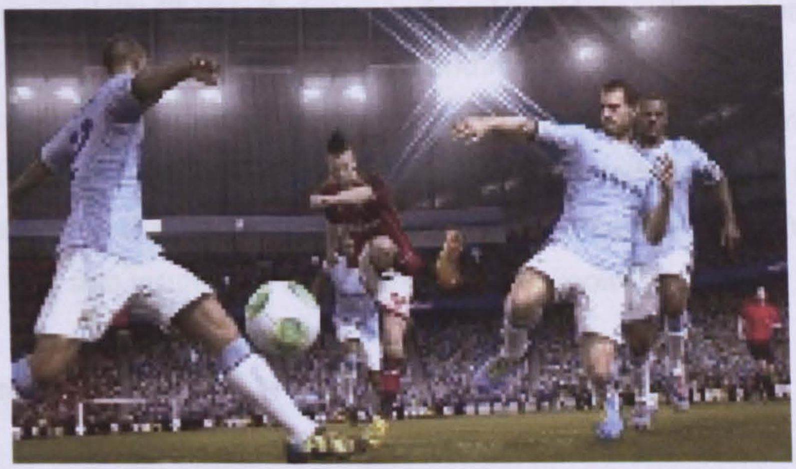

Figure 2.3 Real life character in FIFA 14 (source: http://www.gaming-age.com/2013/12/fifa-14-review-xbox-one-ps4/)

2.3 Pixel Density

The name of pixel is originated from the words Picture Element (PEL). The word "pix" stands for picture while "el" stands for the element. According to Oxford dictionary, any of the tiny individuals that fill on the computer screen, which form the whole screen or whole image is known as pixels (Miranda, 2009). Another definition is the tiniest unit of information or points in a graphic image where it combines together will obtain an image. On the other hand, pixel density is explained as the actual measurement of pixels on the screen surface of certain devices. Not only that, it is also known as the amount resolution of certain devices (Figure 2.4). In addition, pixel density is calculated in pixels per inch (ppi). For instant, a mobile that contain high density means that the pixel quality is high clear. It contains High Quality video output and Gaming Experience. Meanwhile, a low pixel density means low clear which mean the resolution of certain devices are low.

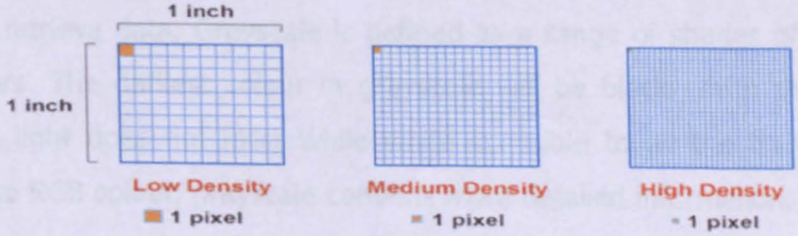

Figure 2.4 The pixel density in 3 categories: Low density, medium density and high density (source: http://www.gsmarc.com/model-finder/pixel-density-range/)

A Linear Pixel Shuffling technique was found to order pixel's position (Anderson, 1993). Linear Shuffling technique is a simple arithmetic progression. The ordering for this technique is designed when pixels in a particular image are chosen, small sub-rectangle will smoothly spread into the entire image. It is a technique that independent of position as well as the pattern size. However, this method cannot differentiate the image noise. It is also insufficient when come to an unknown pattern.

2.3.1 Intensity of Colour

Colour, according to the definition from Oxford Dictionary, is the result of an appearance from an object that the light reflects. The properties of colour is categorised into three: hue, intensity and lightness. Hue, the name given is to assign the pure colour, such as red, green, blue and yellow. Next, intensity can be explained as the appearance of colour according to its brightness. Lastly, the lightness of a colour is the changes in colour depending on the light or dark of the colour. RGB is one of the common terms to define the value of a particular colour.

Colour and depth information give signals about a scene. RGB data consists of information that can be used to detect human face. In other words, RGB data help to detect the current position of human face from camera. An old method View-dependent Pixel Coloring (VDPC) was introduced (Yang, 2003). The basic concept of this method is by using the texture-mapping function to extract the input image to view point. Therefore, in order to decide the colour consistency to be assigned to each pixel, a programmable pixel rendering function is used. However this method obtains data from multiple views of camera (Yang, 2003).

Besides collecting data by RGB, an image also can be converted into grayscale in order to retrieve data. Grayscale is defined as a range of shades of grey without other colours. The darkest colour in grayscale will be black which shows that the transmitted light does not exist while white is visible to all the transmitted light. Compared to RGB colour, grayscale contains more detailed information.

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