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Enhancing Security Using Video Steganography and Water Marking

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ABSTRACT

The rapid development of data transfer through internet made easier to send the data accurate and faster to the destination. Besides this, anyone can modify and misuse the valuable information through hacking. Steganography attempts to hide the secret information and make communication undetectable. Steganography is used to conceal the secret information so that no one can sense the information. Steganographic method has many challenges such as high hiding capacity and imperceptibility.

This paper presents Video Steganography with digital watermarking techniques as an efficient and robust tool for protection.

Keywords—Network Security, Steganography, Water Marking.

1 Introduction

Data security means to protect a database from destructive forces and the unwanted actions of unauthorized users. Huge amount of confidential information is being exchanged over the Internet (publicly open medium) as this is the most cost-effective and widely available way. This technological progress has also made digital data very much vulnerable to interception and then possible unauthorized access / use and has caused significant economical losses for the content producers and rights holders. To protect data on public channels, the security measures need to be incorporated into data communication systems over the Internet [1]. Steganography is one of the promising technologies helping to achieve the overall goal of secure delivery of information from its source to the authorized end-users. Steganography is the art or practice of concealing a file, image, or message within another a file, image, or message. The word steganography is of Greek origin and means "covered writing" or "concealed writing"[2]. Steganography is changing the digital media in a way that only the sender and the intended recipient is able to detect the message sent through it. On the other side steganalysis is the science of detecting hidden message [3]. The objective of steganalysis is to break steganography system and that condition is met if an algorithm can judge whether a given image contains a secret message. To reduce the possibility of attack, security needs to be kept secret i.e. invisible security. The important data can be inserted into multimedia documents in a way that cannot be spotted i.e., imperceptible (invisible) insertion of information into multimedia data. Digital

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Watermarking technique is used to improve the imperceptibility (i.e. invisibility) and robustness. Digital watermarking can be used on any digital image, audio file or text file. Digital watermarking is the process of inserting a digital signal or pattern (indicative of the owner of the content) into digital content. The signal (also known as a watermark) can be used to identify the owner of the work, to trace illegal copies and to authenticate the content of the work.

Steganography and watermarking differ in a number of ways including purpose, specification and detection/extraction methods. The fundamental difference is that the object of communication in watermarking is the host signal with the embedded data providing copyright protection. In steganography, the object to be transmitted is the embedded message and the cover signal serves as an innocuous disguise chosen fairly arbitrarily by the user based on its technical suitability. In addition, in steganography, the third party cannot detect the message in stego media but in watermarking, the third party cannot remove or replace the message. It mainly prevents the illegal copy. Further, the existence of the watermark is often declared openly and any attempt to remove or invalidate the embedded content renders the host useless. The vitally important requirement for steganography is perpetual and algorithmic undetectability. Robustness against malicious attacks and signal processing is not the primary concern as it is for watermarking.

2 Steganography

Steganography is changing the digital media in a way that only the sender and the intended recipient is able to detect the message sent through it. The following formula provides a very generic description of the pieces of the steganographic process [4]:

cover_medium + hidden data + stego_key = stego_medium

In this context, the cover_medium is the file in which is used to hide the hidden_data, which may be encrypted using the stego_key. The resultant file is the stego_medium (which will, of course. be the same type of file as the cover_medium).

Almost all digital file formats can be used for steganography, but the formats that are more suitable are those with a high degree of redundancy. The redundant bits of an object are those bits that can be altered without the alteration being detected easily. Video and image files especially comply with this requirement that can be used for information hiding. In fig 1, shows the four main categories of file formats that can be used for steganography.

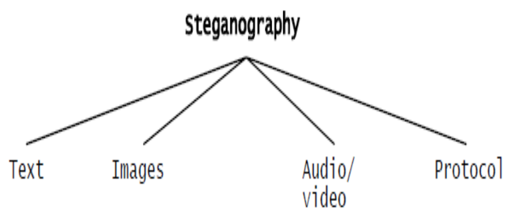

Figure 1: Categories of Steganography

In text, hiding information is historically the most important method of steganography. This method was to hide a secret message in every nth letter of every word of a text message. In video steganography, a digital video consists of a set of frames (images) that are played back at certain frame rates based on the video standards. Video steganography hides the message in any one of the frames/images, after hiding, it is very difficult to examine in which the data/message is hidden [5].

3 Digital Watermarking

Digital watermarking is the process of inserting a digital signal or pattern (indicative of the owner of the content) into digital content. Watermark can be used later to identify the owner of the work, to trace illegal copies and to authenticate the content, of the work. Watermarks of varying degrees of obtrusiveness are added to presentation media as a guarantee of authenticity, quality, ownership, and source. To be effective in its purpose, a watermark should adhere to a few requirements. In particular, it should be robust and transparent. Robustness means it should be able to survive any alterations or distortions that the watermarked content may undergo, including common signal processing alterations and intentional attacks to remove the watermark and used to make the data more efficient to store and transmit. This is so that afterwards, the owner can still be identified. In transparent, requires a watermark to be imperceptible so that it does not affect the quality of the content and makes detection.

4 Least Significant Bit

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

Least significant bit (LSB) insertion is a simple approach for embedding information in a cover image. The least significant bit (i.e. the 8th bit) of some or all of the bytes inside an image is changed to a bit of the secret message. In this 24-bit image, a bit of each of red, green and blue color components can be used, and they are each represented by a byte. In this example, a grid for 3 pixels of a 24-bit image can be as follows:

(00101101 00011100 11011100)

(10100110 11000100 00001100)

(11010010 10101101 01100011)

If the number 200, the binary representation is 11001001, is embedded into the least significant bits of this part of the cover image, then resulting grid is:

(00101101 00011101 11011100)

(10100110 11000101 00001100)

(11010010 10101100 01100011)

So if the number was embedded into the first 8 bytes of the grid, only the three in bold and underlined bits needed to be changed according to the embedded message. On average, only half bits in an image will need to be modified to hide a secret message using the maximum cover size.

5 Discrete Wavelet Transform

DWT (Discrete Wavelet Transform) is used for digital images. Many DWTs are available. Like to hide text message, integer wavelet transform can be used. The simplest transform is haar transform. DWT is the multi resolution description of an image. DWT splits the signal into high and low frequency parts. The low frequency part is split again into high and low frequency parts, while the high frequency part contains information about the edge components. The high frequency components are usually used for watermarking since the human eye is less sensitive to changes in edges. DWT transform is applied to an image it is decomposed into 4 sub bands: LL, HL, LH and HH. To perform a second level decomposition, again DWT is applied to LL1 which decomposes the LL1 band into the 4 sub bands [6]. Fig 2 shows a second level decomposition.

Haar Transform decomposes each signal into two components, one is called average (approximation) or trend and the other is known as difference (detail) or fluctuation.

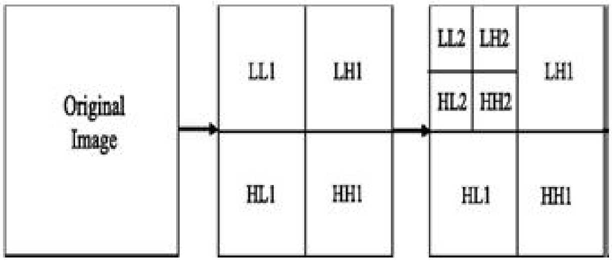

Figure 2: Level 2D – DWT

A precise formula for the values of first average sub signal, $a=a_1,a_2,a_3,....a_{N/2}$ at one level for a signal of length *N* i.e. f = (f1, f2......fn) is [6]

$$a_n = \frac{f_{2n-1} + f_{2n}}{\sqrt{2}}, n = 1,2,3, \ldots .N/2$$

and the first detail sub signal, $d^1=d_1,d_2,d_3,\ldots d_{N/2}$, at the same level is given as

$$a_n = \frac{f_{2n-1} - f_{2n}}{\sqrt{2}}, n = 1,2,3, \ldots .N/2$$

6 Discrete Cosine Transformation

DCT has strong robustness and is widely used in digital image watermarking. DCT transforms a time domain signal into its frequency components. Many frequency coefficients are obtained from DCT, such as single direct current DC coefficients, low frequency, mid frequency coefficients, and high frequency coefficients. These middle frequency bands are chosen such that they avoid the most visual important parts of the image (low frequencies) without over-exposing themselves to removal through compression and noise attacks (high Frequency).

Consider a subimage g(x,y) of size n×n whose discrete transform T(u,v), can be expressed in terms of general relation [7],

$$\mathrm{T(u,v)} = \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} g(x,y) r(x,y,u,v)$$

$$\mathrm{r(x,y,u,v) = s(x,y,u,v)} \quad = \alpha(u)\alpha(v)\cos[\frac{(2x+1)u\pi}{2n}]\cos[\frac{(2x+1)v\pi}{2n}]$$

Where

$$\alpha(u)\alpha(v) = \begin{cases} \sqrt{\frac{1}{n}} & for\ u = 0 \\ \sqrt{\frac{2}{n}} & for\ u = 1,2, \ldots \ldots, n-1 \end{cases}$$

Given T(u,v) , g(x,y) similarly can be obtained using inverse discrete transform

$$g(x,y)= \sum_{x=0}^{n-1} \sum_{y=0}^{n-1} T(u,v)s(x,y,u,v)$$

7 Problem Formulation

Many Video Steganography techniques have been proposed earlier but they were not secure enough and can be temporarily tampered with so the task was not fulfilled. Even if the message is encoded before sending the message, this can be decoded by the hacker by making use of certain algorithm. Video Steganography alone could not provide better results as technique used for video steganography with LSB was not good enough. Results of previous PSNR obtained were poor and unsatisfactory. Many problems exist with the already proposed algorithm in the literature. To overcome these problems this thesis work designing a new algorithm for data security.

8 Objective for Study

- To analyze different techniques proposed in literature for data security during message transmission.
- To provide better security and transfer of data from source to destination
- To improve robustness without perceptible distortion.
- To provide a better PSNR and MSE results of proposed algorithm.

9 Proposed Algorithm for Data Security

In this paper, a new algorithm is proposed for better data security and transferring of data from source to destination. A good approach to video steganography with watermarking should aim at concealing the highest amount of data possible in a cover video while maintaining imperceptibility, that is, an acceptable level of visual quality for the watermarked video.

9.1 Hiding technique for hidden information (Embedding Process)

The embedding process takes a cover video and a secret message as the inputs.

- **Step 1:** First take an original video as cover video. Then convert it into number of frames or images. Then select a particular frame/image; this will act as cover image.
- **Step 2:** Add a password graphically for more security.
- **Step 3:** Load a secret text which embed into the cover image and convert it into binary form.
- **Step 4:** Then apply the LSB technique. The LSB bit of the image pixel is replaced by the binary data. Then get a stego-image.
- **Step 5:** Apply the combined DWT and DCT technique to stego-image. Get the watermarked image.
- **Step 6:** At last, have a watermarked video. This video is ready for the transmission through the internet.

9.2 Recovery technique of hidden information (Extracting Process)

It basically follows the reverse process of the hiding algorithm to obtain the secret message.

Steps to recover the hidden information:

- **Step 1:** Load the watermarked video.
- **Step 2:** Enter the password to get the secret message.
- **Step 3:** Apply the inverse DWT and inverse DCT technique to get the stego image.
- **Step 4:** Apply the LSB technique on the stego image.
- **Step 5:** Get the secret message and original video.
- **Step 6:** Finally, we analyze the result on the basis of PSNR, MSE and histogram.

10 Result and Discussion

In previous work, Sunil K. Moon et. al (2013) [8] used cryptography and steganography. In proposed algorithm, steganography with watermarking are used which provides more security than in previous work. In this, results of all the intermediate steps of the proposed methods are highlighted. Implementation is done on MATLAB Experimental results of intermediate steps show the efficiency of the proposed approach. Results includes following steps:

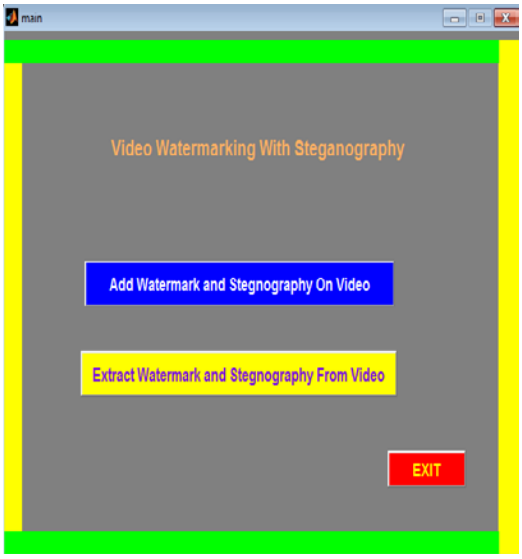

Figure 3: Opening GUI

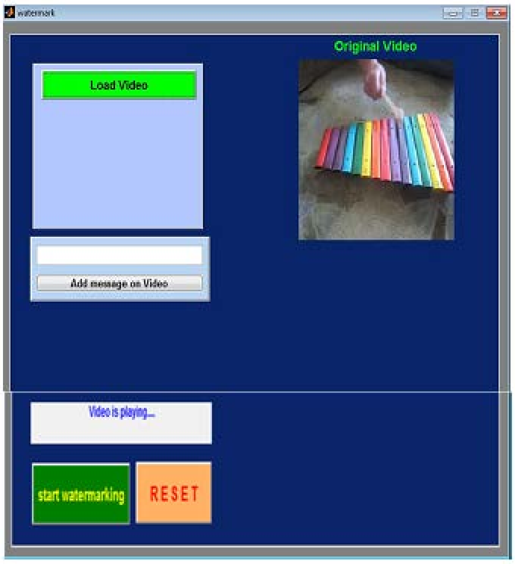

Figure 4: Input Video is loaded

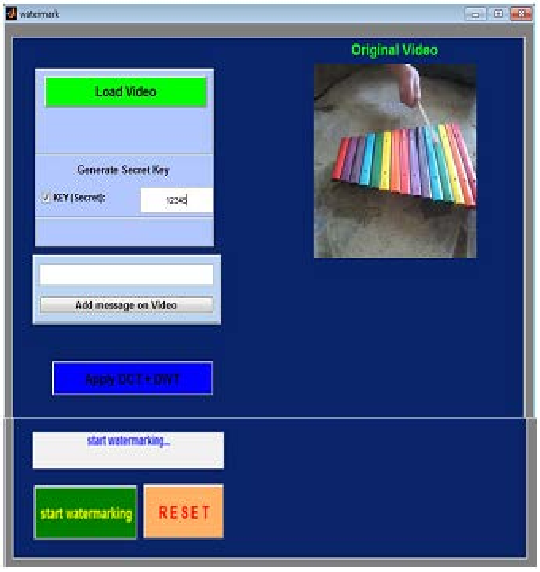

Figure 5: Password is added

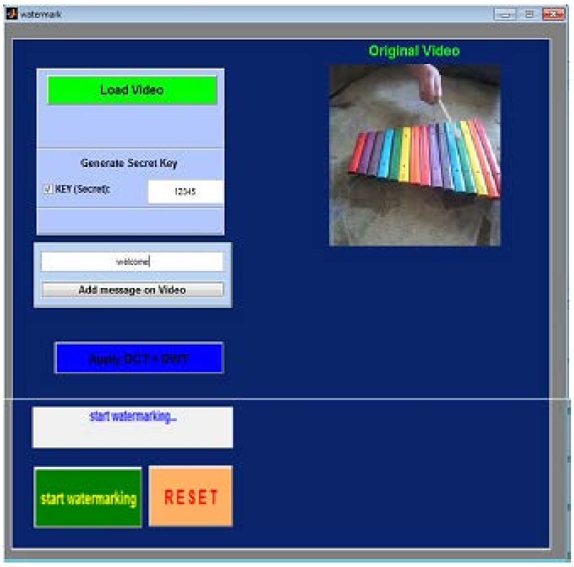

Figure 6: Secret message is added

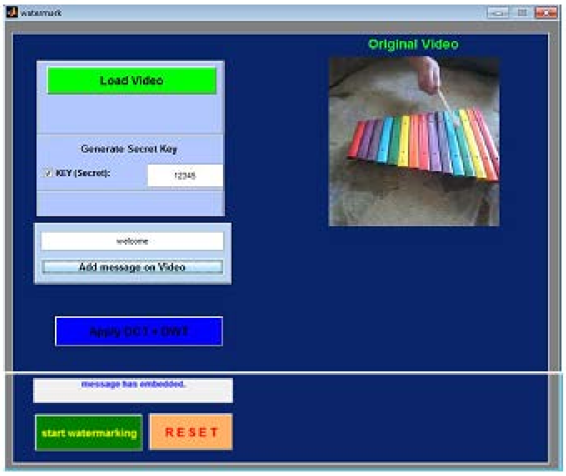

Figure 7: Steganography is applied

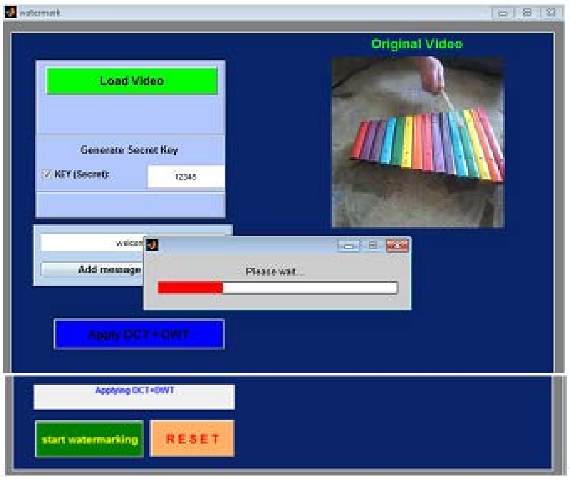

Figure 8: Applying DCT +DWT

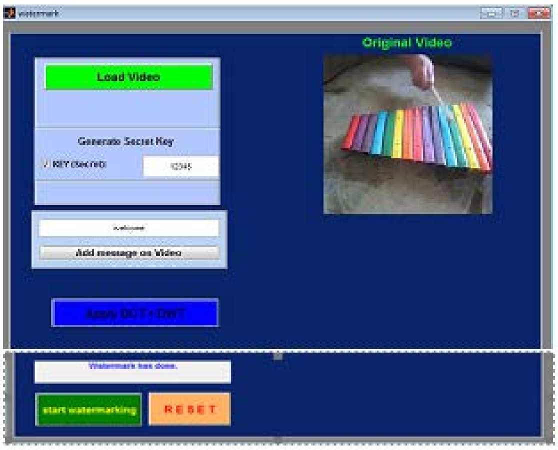

Figure 9: Watermarking is applied

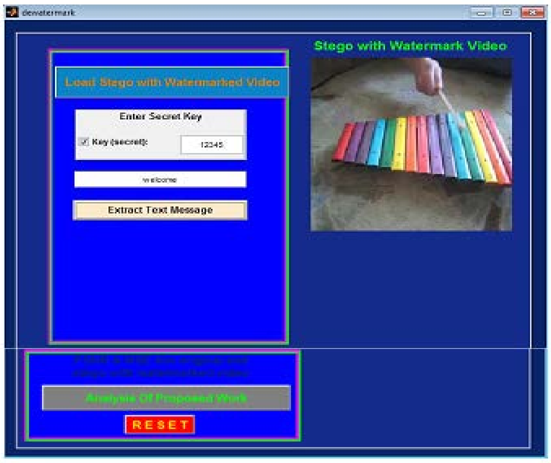

Figure 10: Decoder Side, Message is extracted

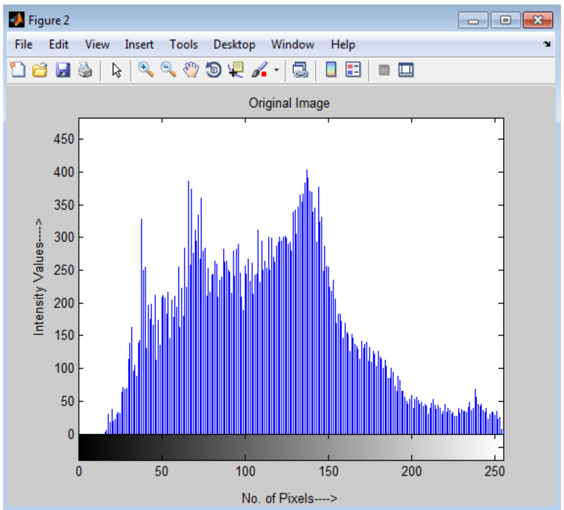

Figure 11: Histogram of Original image/Frame

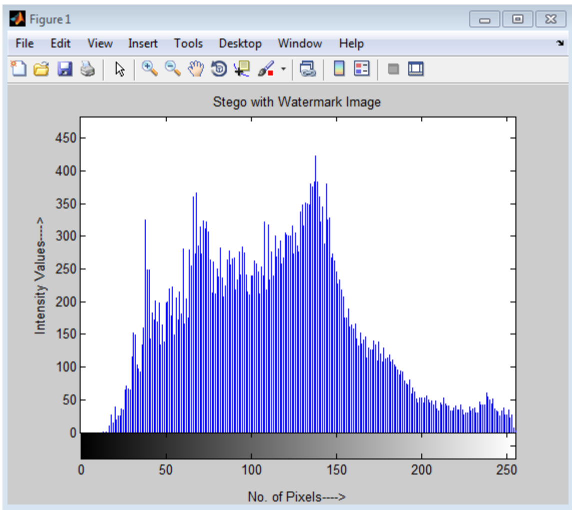

Figure 12: Histogram of watermarked image/Frame

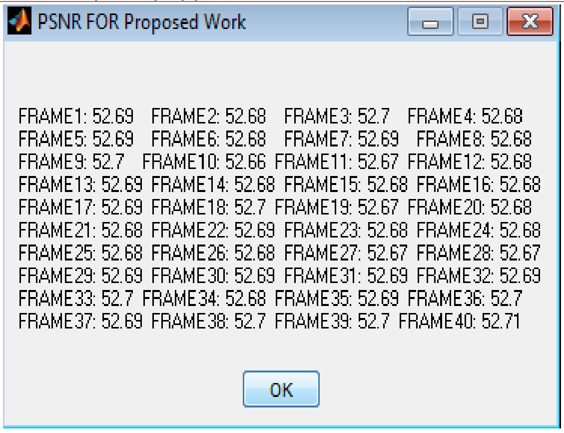

Figure 13: PSNR for Proposed work

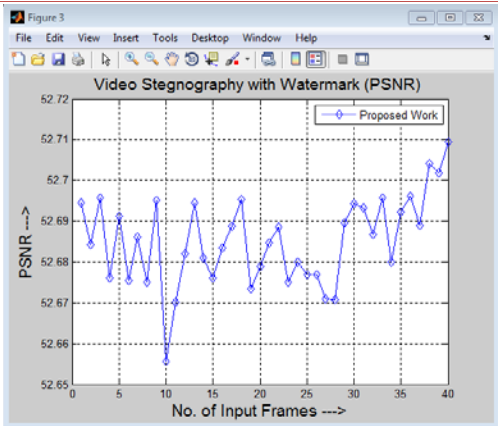

Figure 14: Graph of PSNR values for proposed work

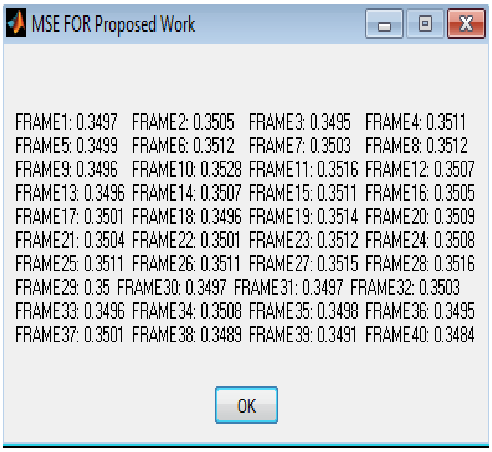

Figure 15: MSE for Proposed work

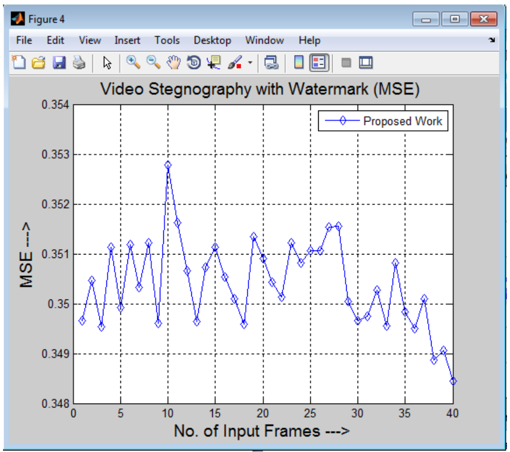

Figure 16: Graph of MSE values for proposed work

11 Conclusion and Future Scope

In this thesis we have presented a new system for the combination of Steganography with watermarking which could be proven as a highly secured method for data communication in near future. The proposed High secured system using steganography and watermarking is tested by taking message and hiding them in images/frames of input video. The results that are obtained from these experiments are recorded. The Proposed algorithm provides more security in comparison to previous algorithm proposed by Sunil. K. Moon et. al.(2013). Future Work may be further enhancement of results by applying some other algorithm than used in this thesis. We can also take two videos as input and can embed secret message in both. Other quality metrics can be used to judge the performance of the algorithm.

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Approaches for the Racial and Ethnic Determination of a Person

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ABSTRACT

The article describes the approaches for the racial and ethnic determination of a person. Ethnic belonging of any person is one of his groups of signs; hence, the need for its study may be due to a variety of reasons, such as the recognition of a person's face, creating identification card, making up the image of an unknown person, or of a missing person or suspected criminals, and so on.

Keywords: Face, recognition, ethnic groups, criminals, determination

1 Introduction

Many professional areas of (customs, border control, security services, etc.) might be interested in the theoretical and practical studies on the racial and ethnic identification of a person. Solution of this issue may reduce the time spent for the search of millions of photos stored in the database during the recognition of a person on the basis of images, as well as decrease the scope of the search significantly.

A number of specialists of various affiliations are engaged in solving the problems of racial and ethnic determination of a person. Existing problems in this area are solved with the use of different methods.

The researchers specialized in the humanitarian field, such as Anthropology, Ethnography and Race studies, as well as other experts in the technical sciences, as Biometric technologies, Pattern recognition, Medicine, and so deal with the solution of the current problems.

Developed and tested methods of identification and evaluation of individual psychological characteristics of people of different racial groups by photographs of their faces [1].

Ethnography is originated from the combination of the Greek words"ethnos"(people), and"grafis"(to describe). The main objective of ethnography is to study the nations and to explore their history.

Some methods in the field of ethnography are:

- The method of value orientations by Rokich;
- Cognitive-communicative method;
- The method of "Who am I" by Kuna-Makpartlend;
- The method of stereotypes research;
- The method of "Writing additional qualities" by Stefanenko;
- Bipolar schedules for studying the dependence of the personal qualities on the nation, and so on.

Some trends in the field of Ethnography:

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- Primordialism. This approach assumes that the ethnic belonging of a person originates from the nature orthe society and exists objectively;
- Dual theory of ethnic groups;
- Social biological direction;
- Pierre Den BergheTheory;
- Passionate ethnos theory by Gumilev;
- Constructivism;
- Instrumentalism and others.

Anthropology (anthropos – human, logos - science) a natural science about a humanity. It studies the formation and development of the humanity, the emergence of human race, and the common changes in the physical structure of human is shown in Figure 1.

Anthropology is a field of science the subject of which is a human.

Race studies (or ethnic anthropology) the branch of anthropology that studies and explores the emergence origins of races, race types, its classification and distribution areas on the Earth, the compliance of the racial types with the changes [2, 3].

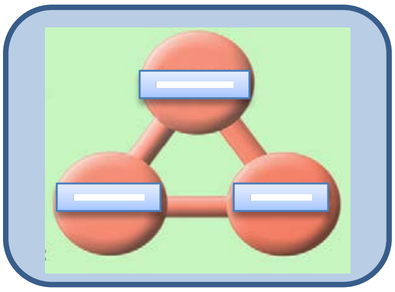


Figure 1. Social fields of the racial and ethnic determination of a human

The concept of race was first used in 1684 by French ethnographer and traveler Francois Berne.

Race is a group of people who formed in a certain geographic region and share similar genetic and distinct biological characteristics. The characteristic features of the various human races are possible as a result of adaptation to a certain environment.

In another source the race is defined as large groups of people differing by the physical features passed from generation to generation historically inhabited in a particular area.

A complex of physical signs have emerged as a result of the adaptation to the environment, due to which three main races of the peoples all over the world were distinguished: “white”, “black” and “yellow”, respectively europoid, mongoloid and. negroid Lately, it is recommended to distinguish an amerikanoid race from mongoloid race.

Ethnicity (Greek.῎Εθνος (ethnos) nation) isa historical complex of people having culture and psyche with relatively stable features, as well as of the people differing from others and speaking in own language.

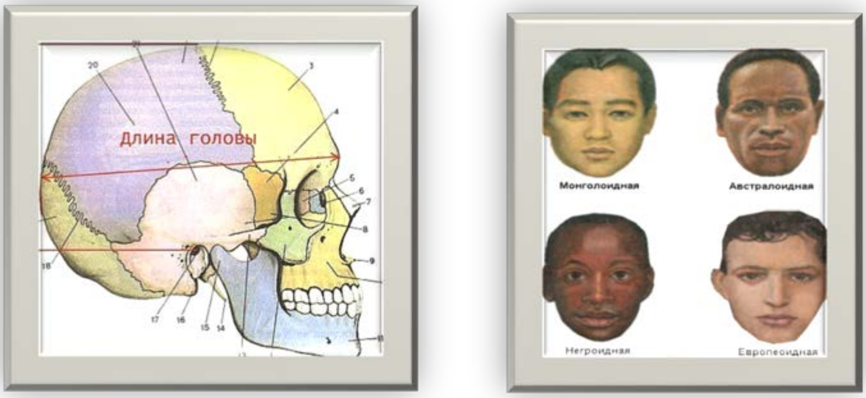
Ethnogeny [Greek. ethnos - people and genesis - birth] is the origin of any nation [4].

2 Some Problems of Racial or Ethnic Determination of a Person

Some problems of racial or ethnic determination of a person:

1. According to the bones of the skull;

2. According to the face images;
3. According to the finger and palm patterns;
4. According to eye;
5. According to teeth and so on. (is shown in Figure 2).



According to the bones of the skull

According to the fingerprint patterns

According to the eyes

According to teeth

Figure 2

- Racial or ethnic determination of a person according to the bones of the skull (the bones of the skull is the object of the study):
- Problem solving and conducting experiments according to the given methods;
- Measuring the indicators;
- Comparison with the figures in the table;
- Determination of the race [5].
- Racial or ethnic determination of the race. of a person according to the face images.

In some issues the following features of a human face are used (is shown in Figure 3):

- The height of the forehead the upper part of the nose;
- The distance between the inner and outer corners of the eyes;
- The distance from the tip of the nose to the chin;
- The width of the nose;
- The distance from the top of the nose to the tip of the nose;
- The distance from the tip of the nose to the center of the lips [6].

Among different approaches for 3D face recognition, solutions based on local facial characteristics are very promising. However, so far, a few works have investigated the individual relevance that local features play in 3D face recognition.

The proposed solution is experimented using facial scans of the *Face Recognition Grand Challenge* dataset [7].

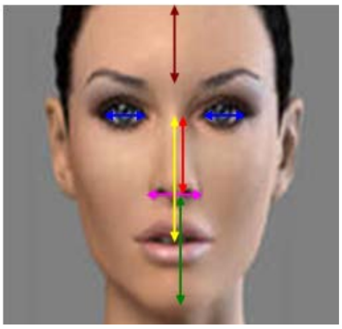


Figure 3. Some signs of the human face image

Racial or ethnic identification of a person according to the finger and palm patterns

Dermatoglyphics (from ancient Greek word Δέρμα, (b P. Δέρματος - skin and γλύφω–carving)studies the skin patterns of the palms and soles of a person.

Dactyloscopy (Greek. Δάκτυλος - finger and σκοπέω - look, observe) an identification method of a person according to the finger prints on the skin, and relies on the patterns observed in individual prints (is shown in Figure 4).

Currently, the most common applications characterize the papillary patterns of the fingertips [8].

Figure 4. Racial or ethnic determination of a person according to the eyes

Gustav Fritsch (1839-1891) first showed the racial differences of the cellular retina of the eyes [9]. The cellular retina is a thin nerve membrane of the front side of the back wall of eyeball (is shown in Figure 5).

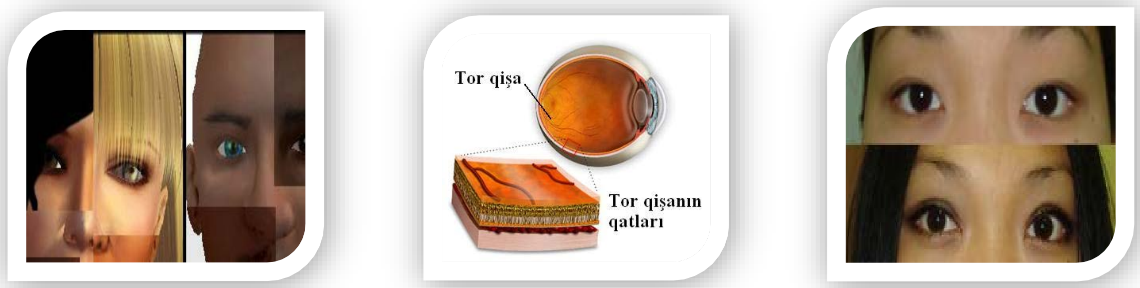


Figure 5. Racial or ethnic determination of a person according to the teeth

Dental identification determines a person's racial and ethnic identity according to his teeth.

The teeth of each individual has the unique characteristics. The mandible, where the teeth are located,is also used here [10].

3 Human Face Determination according to the Racial Features

As the human face is the source of most of information signals, it is supposed that in the east, they could predict a person's life according to his face. A person's face is the center of the human behavior and communication, and it has a capacity.As a rule,the face is described in two projections:

- En face;
- Profile.

According to the human face the age, sex and ethnic origin and race can be identified.

Scientists have used a variety of methods for the racial or ethnic determination of a person according to his face. As a result, it has been suggested that the person belongs to one of the three races europoid, mongoloid and negroid according to the geometric signs of the face. In these cases, 11 points of a person's face are used. Diverse methods have been applied for the human face recognition according to these points [11].

In other identification issues certain parameters of the human face image were set. The work targeted at the racial identification of the person according to his front side (en face) image.

The survey revealed that the proportion of the head, the width of the mandible, the shape of the nose and lips, the edge of the eyes and so on are the main parameters. Relative parameters should be used in order to work with these criteria:

- Proportionality of the head - the correlation of the width of the face to its height (3 points)
- The correlation of the width of the forehead to the width of the mandible (2 points)
- The correlation of the width of the nose to the width of the mandible (2 points)
- The correlation of the width of the lips to the width of the mandible (3 points)
- The correlation of the width of the eyes to their height (3 points)

The standard descriptions of the representatives of the races are stored in the database according to the developed methods. The points of the parameters are used for the determination of some races. If the initial parameters are similar to the standards, then the scores are recorded. All parameters area analyzed, the most identical face parameters of any race are defined [12].

4 Results

Research works are carried out in this field at the Institute of Information Technology of ANAS.

The study examines the racial and ethnic identification of a person according to his face image. The standard images are developed according to the certain geometric points of the face and the special algorithm for the calculating of the certain parameters of the images stored in the database (is shown in Figure 6). Then, the initial image is compared to the images of various ethnic groups stored in the database, and thus, the racial and ethnic identification of the person is defined [13-14].

Figure 6. Standard images

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Patches Detection and Fusion for 3D Face Cloning

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ABSTRACT

3D face clones are used in many fields such as video games and Human-Computer Interaction. However, high-resolution sensors generating high quality clones are expensive and not accessible to all. In this paper, we propose to make a fully automated and accurate 3D reconstruction of a face with a low cost RGB-D camera. For each subject, we capture the depth and RGB data of their face in different positions while performing a rotational movement of the head. We fit a 3D Morphable Face Model on each frame to eliminate noise, increase resolution and provide a structured mesh. This type of mesh is a mesh which the semantic and topological structure is known. We propose to only keep the suitable parts of each mesh called Patch. This selection is performed using an error distance and the direction of the normal vectors. To create the 3D face clone, we merge the different patches of each mesh. These patches contain relevant information on the specificity of individuals and lead to the construction of a more accurate clone. We perform quantitative tests by comparing our clone to ground truth and qualitative tests by comparing visual features. These results show that our method outperforms the FaceWarehouse process of Cao et al [2]. This 3D face clone on a structured mesh can be used as pretreatment in applications such as emotion analysis [13] or facial animation.

Keywords: Structured mesh, Patches detection and fusion, 3D Morphable Face Model, Fitting

1 Introduction

Face Cloning is an important area of research in Computer Vision and Graphics. Indeed, it can be used in many applications, such as video and serious games, e-learning and Human Computer Interaction where the user must be able to interact with the computers. Actually, these applications must assist machines to automatically detect specific information about the user such as hand, arm and face gestures. A lot of research is conducted to improve such applications. R.Gross et al [8], C.Soladie et al [11] and A.Väljamäe et al [12] show that systems which adapt to the specificities of the subjects perform better than generic systems. For this reason, the use of a 3D face clone of the user rather than a generic face model as pretreatment increases the performance of these applications, K.A.Funes Mora and J.Odobez[7] shows for example that the use of a 3D clone to detect the pose of the head and eyes provides excellent results. That is why to improve the reconstruction techniques; realistic 3D clone can increase the performance of these applications. Moreover, the necessary infrastructure shall be available to end-users at their homes. Therefore, the sensor must be inexpensive and the method must be fully automatic. For all these reasons, low-resolution cameras have been recently used in the field of facial clones. Furthermore, we must know the semantic and topological structure of meshes so that the 3D clones can be used in applications. We call this type of mesh, a structured mesh. For instance structured mesh allows the detection of characteristic points used identifying a person's emotions [13].

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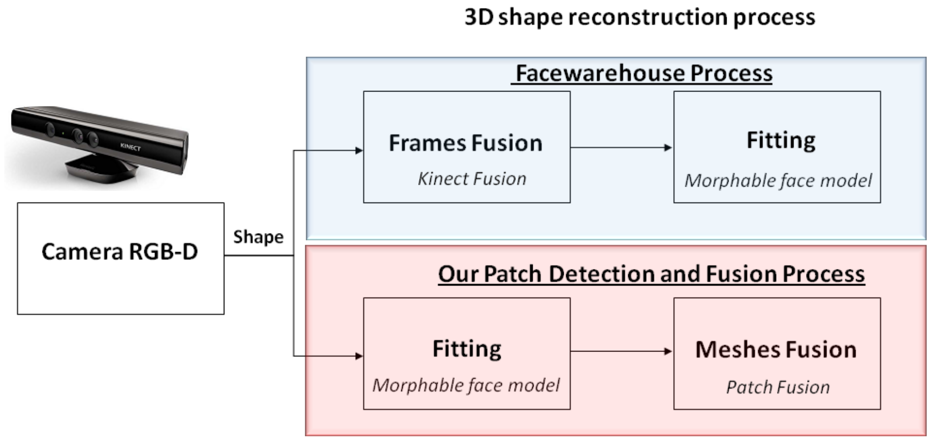

Figure 1: Comparison of 3D shape reconstruction process

There are several types of sensors for obtaining realistic clones. In the literature, certain methods use 2D data (RGB) to reconstruct the 3D shape and texture. Light Stage is a 2D high-resolution scanner that captures the properties of light (in texture and reflectance) of any object. This technology was developed in California by P.Debevec [5]. This method uses the specific properties of the skin. It consists of several light sources (LED), several digital cameras and electronic system for controlling the light and the RGB camera. Highly realistic clones can be obtained but is very expensive and not accessible. The web service AutoDesk 123D Catch permits to create realistic clones from 2D images but it does not provide structured clones. In addition, we need the help of a second person to create his clone. There are also several types of high-resolution 3D sensors for obtaining hyper realistic clones. This type of sensor is used to achieve very satisfactory results in terms of accuracy and realism but they are not feasible for domestic use. They are used to create databases and ground truth. Indeed Inspeck Mega Capturor II 3D has created the basis of the Bosphorus data with an accuracy of 0.3 mm ref [9]. It makes it possible to acquire depth data with structured light. P.Paysan et al [10] use a coded light system created by ABW-3D. They measure the shape of an object using a sequence of light patterns. This scanner provides realistic clones with high resolution. It was used to design the database of their Morphable Face Model [10].

In this paper, we propose a system for 3D face cloning using a low-cost sensor (Kinect) and providing a structured high resolution 3D clone. With this sensor, we obtain noisy low-resolution depth and color data. Therefore, we fit a Morphable Face Model [10] on each 3D depth frame (Figure 2). This has two advantages: 1) it enables to increase the resolution and reduce the noise for each 3D depth frame 2) it enables to know the structure of 3D facial mesh. We obtain for each frame a structured 3D mesh. Our process is completely automatic: we have no manual training phase. In response to realism, we propose a method for detecting and merging parts of the obtained meshes (patches) that are adequate. Indeed, we identify patches contain relevant information on the specificity of an individual. Finally, we merge all of these patches. This approach allows us to provide a realistic 3D clone.

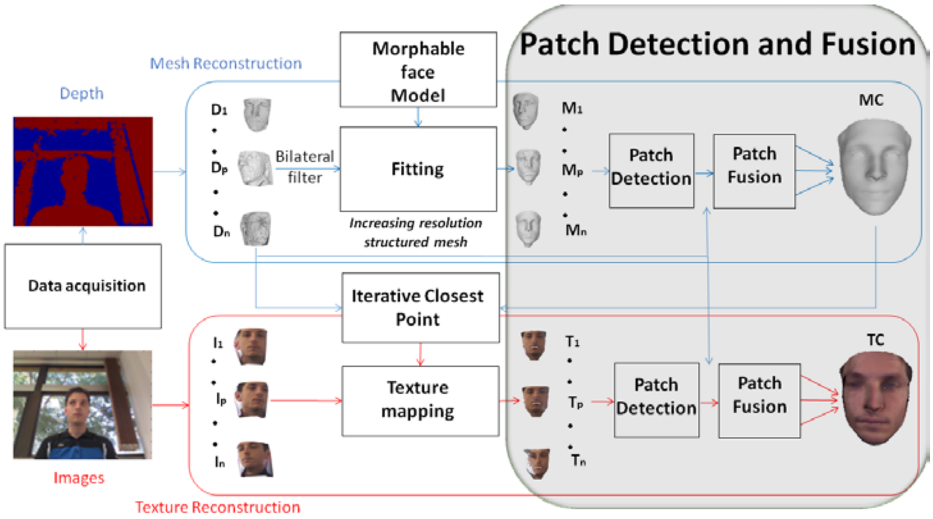

Figure 2: Our patch fusion for 3D face cloning system

The first main contribution of this paper is at the system level. Most of the methods first perform frames fusion and then a Morphable Face Model (Figure 1). In the FaceWarehouse process, C. Cao et al [2] fit a Morphable Face Model on a mesh obtained with Kinect Fusion. The peculiarity of our method is to reverse the process. We first perform the fitting on each depth frame and then the fusion. Under these conditions, the system is less dependent on alignments and fitting errors because we merge a posteriori only reliable information. Our second main contribution is the patches detection and fusion technique. When we use a Morphable Face Model, some of the morphological specificities of the individual that we want to clone may disappear. Indeed, the entire Morphable Model does not contain all possible forms and details of the unknown new face in its entirety. The specificities of the individual can only be found if they belong to the database. That is why we used a method that selects small patches (carefully chosen set of points) that focus on the details of the specificities of the individual. That is, we identify the parts (patches) of each 3D meshes that are relevant using an error distance and the direction of the normal vectors at each point of the face. Our approach allows finding specificities of persons that are not found with a conventional method of fitting [16]. We use this method both on the texture and on the depth data.

This article is organized as follows. In the next section, we present several methods for cloning 3D face that exist in the literature. In Part 3, we describe the various components of our patches detection and fusion algorithm on form and texture. Part 4 demonstrates the accuracy and the precision of our results by comparing them to other methods. Section 5 concludes the paper.

2 Related Work

There are several techniques for cloning 3D face with low resolution RGB-D sensors. During the past decade, these sensors have often been used in research because they aren't expensive and are accessible to general public. These methods can be classified into two categories of methods: techniques to obtain an unstructured mesh and those which give structured one. A structured mesh is a mesh for which we know the correspondence of each 3D point with the face that we want to clone (figure 3).

R.A Newcombe et al [17] present a 3-D reconstruction of scenes or objects using a depth low cost camera. Kinect Fusion provides high quality 3D scans. The algorithm consists of 3 steps. First Iterative Closest Point algorithm is used to determine the position of the camera. Then, they use a surface volumetric representation [18]. And finally they perform a ray casting for rendering depth data. To increase the resolution of the depth map, Y. Cui et al [4] use a method of super-resolution [19]. This method creates a high resolution depth map from multiple low resolution depth maps. It combines low resolution depth maps with a perspective slightly different from the static object. This approach gives less noisy and smoothed frames. Then each frame is aligned to reconstruct the 3D face using a probabilistic alignment method [20]. Q. Sun et al [15] propose a method for reconstructing a 3D face from RGB and depth data captured with low resolution Kinect. First, it detects the person's face by using the RGB data. Then they use bilinear interpolation to increase the resolution of depth frames. Finally, they combine four frames high resolution depth for a realistic 3D face. They use an energy function that will allow to combine the frames of depth but also to smooth the final result. All these methods enable to clone realistic faces but are limited in terms of precision of facial features. For example, the low resolution sensors do not reflect the accurate shape of the face at the vicinity eyes. Because of the infrared reflection in the eyes, the sensor does not return the shape of the eyeball (Figure 11). Moreover, they do not provide structured 3D clones and therefore cannot be directly used as a pretreatment in applications requiring knowledge of the correspondence of the mesh points with the face. Below, we present the teams that get this type of 3D clone.

Techniques using deformable models can reconstruct 3D structured clones and eliminate noise depth data provided by RGB-D sensors. M.Zollhöfer et al [21] present an algorithm for 3D clones from high resolution RGB and depth data obtained with a Kinect camera. First, they smooth depth frame (Gaussian filter), detect feature points from the corresponding RGB image and segment the face using 3D depth. Then, they fit a Morphable 3D Face Model on the frame depth obtained by minimizing an energy term. Eventually, they project an RGB image on the 3D face reconstructed to obtain a 3D clone with a texture. C. Cao et al [2] create a database of 3D faces of 150 individuals. For each person, they capture with the RGB-D Kinect camera data from 15 different expressions included the neutral face. They then use Kinect fusion [17] to reconstruct the 3D face of each person. For each of these 3D faces, they detect 74 feature points using an Active Shape Models (ASM) [23] on the corresponding RGB images. Some points are manually adjusted for greater accuracy. Then, they fit a Morphable Face Model [10] on the 3D faces using an energy term. The model is deformed to adapt as effectively as possible 3D faces while matching characteristic points. Finally, they get a structured 3D mesh of each expression for each person. Note that their method is not fully automatic. M.Zollhöfer et al [14] presents an iterative method to clone the 3D face of a person. First, they detect the pose of the head and use a method similar to Kinect fusion to merge the different frames of depth and texture. Then, they detect the characteristic points of the face and they fit a statistical 3D face model [10] to reconstruct the shape and texture of the face. To do this, they optimize an energy term that finds the shape, albedo and illumination. They iterate these 4 steps for each new depth frame.

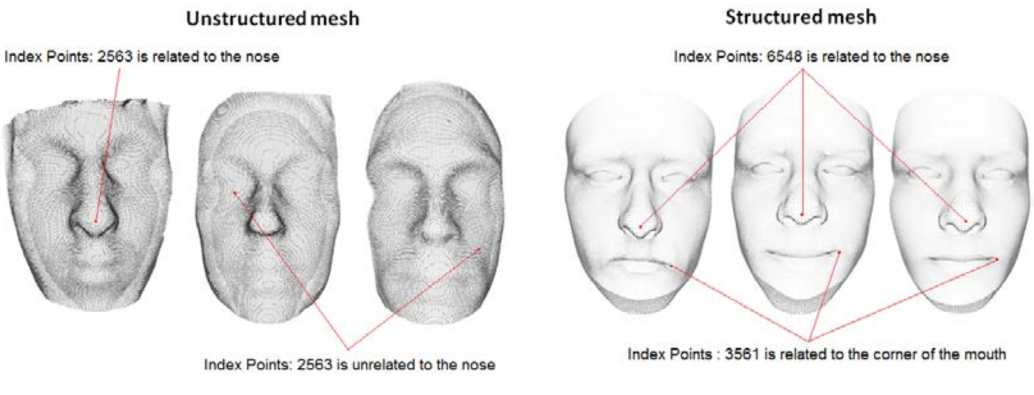

Figure 3: Definition of a structured mesh

The resulting 3D structured mesh obtained from these methods can be used in various applications such as a pre-process for gaze detection. Indeed, K.A.Funes Mora and J.Odobez [7] use 3D clones to estimate the pose of the head and the direction of the gaze of a person. To obtain a 3D clone, they fit a Morphable Face Model on data captured with a Kinect camera. Their method requires manual placement of feature points. They then use an algorithm based on Iterative Closest Point algorithm to detect the laying of the head. All the methods previously described above uses a Morphable 3D Face Model. They can provide high resolution structured clones. These techniques depend heavily on the quality of the model's face. Indeed, the specificities of the individuals can only be found if they belong to the database. It is therefore essential to use a database composed of diversified faces. The use of feature points can improve the fitting. But the methods are sensitive to the precision of the detection of these points. That is why most of these methods need manual adjustment of the points.

Our method of detection and fusion patches belongs to the category of techniques that use a Morphable Face Model but is fully automatic. Our technique is less dependent on the quality of the model used. Indeed, the goal of our algorithm is to improve the results of cloning using deformable models used in this type of methods.

3 Patches Detection and Fusion method

The different parts of our method are described in Figure 2. For each person, we capture various color and depth data of different views of the face. These data are noisy and in low resolution. We obtain a 3D point cloud (real coordinates: X, Y, Z and color: R, G, B) giving information about the subject's face. Our algorithm consists of two main sections: the reconstruction of the 3D shape (section 3.1) and the reconstruction of the 3D texture (section 3.2). For the reconstruction of the 3D shape, we use a Morphable Face Model. Compared to conventional methods, our process is reversed: we first perform a fitting with a Model on different depth frames Dp (p = 1 to n) to increase the resolution and remove noise and then we perform a fusion of the structured obtained meshes Mp (p = 1 to n) (Figure 1). We obtain a structured clone without texture Mc. In section 3.2, we describe the steps to rebuild the texture of the clone Tc. We explain how we map and merge the different texture images Ip (p = 1 to n).

3.1 Mesh Reconstruction

The first section of our process is the reconstruction of the 3D shape of the face. It is composed of two sub-sections: the fitting (3.1.1) and detecting and merging patches (3.1.2). The fitting and the patches detection are performed on each of the frames. Then we merge the obtained patches.

3.1.1 Fitting with a Morphable Face Model

The fitting is applied to each depth frame Dp (p = 1 to n). It is composed of a pretreatment and the iteration of two main stages. First, we perform preprocessing by filtering each depth frame Dp to remove part of the noise. Then, at each iteration, we align the depth frame Dp with the Morphable Face Model mesh S(α) (rigid transformation), and finally we deform the mesh S(α) so that it takes the shape of the depth frame Dp (non-rigid transformation). Each step is described below.

Bilateral Filter: Each depth frame Dp is smoothed with a bilateral filter before being treated [6]. This is a non-linear filter which has the advantage of preserving the edges and remove noise.

Rigid alignment: At each iteration of the fitting, we first need to align each depth frame Dp with the Morphable Face Model mesh S(α). The vector α is the parameter vector of the Morphable Face Model. We use the well-known and often used, iterative algorithm Iterative Closest Point [1], which aligns two 3D point clouds (rigid transformation). It consists of two stages: at each iteration, we match the points of $\mathrm{S}(\alpha_p)$ with the points of the depth frame Dp and then we estimate the rotation R and translation T matrix. Minimization of the error metric E_{icp} (equation 1) is used to estimate these two matrices.

$$\mathrm{E_{icp}(R,T) = arg\,min_E} \left\| \mathrm{S}(\alpha_p) - (\mathrm{R} * \mathrm{D_p} - \mathrm{T}) \right\|^2 \qquad \text{with p = 1 to n} \tag{1}$$

The error E_{icp} is based on the Euclidean distance between pairs of points in 3D point clouds that we want to align. Finally, these transformations R and t are applied to the frame Dp at the beginning of the next iteration. We iterate these two steps until the error Eicp reaches a minimum threshold or until the maximum number of iterations is reached. There are many variants of the ICP algorithm. S. Rusinkiewicz et al [22] compared the convergence characteristics of several ICP variants. For example, they used different distances (color, Euclidean ...) to match the points of two clouds to be aligned. In our method, we use the point to plan ICP of Y.Chen et al [3]. It is slower than the point to point but provides a better alignment of the two 3D point clouds. In the ICP algorithm, it is important to reject a maximum incorrect pairs of points. Therefore, we use a distance criterion to determine if a match is correct or not. We reject 50 percent of pairs of points.

Non-rigid transformation: After making the rigid transformation, we distort the average mesh $\bar{S}$ of the Morphable Face Model to fit to the depth frame Dp. In our process, we use Basel Face Model [10] to perform the non-rigid transformation. To compute this parametric model, they have made a principal component analysis (PCA) on 200 3D faces.

$$\mathrm{S}(\alpha) = \bar{\mathrm{S}} + \mathrm{U} * \mathrm{diag}(\sigma) * \alpha \tag{2}$$

In this equation, U is the orthonormal basis of the principal components of the PCA and σ the standard deviation of the components. The modification of the vector α provides the ability to distort the average face $\bar{S}$ to create a new 3D face. We compute a distance error E_{fit} between the points of depth frame Dp and the mesh $S(\alpha_p)$ and we are looking for the α_p that minimizes this error:

$$E_{fit} = \mathrm{arg}\,min_E \left\| W_p .* \left(S(\alpha_p) - D_p\right) \right\|^2 \qquad \text{with p = 1 to n} \tag{3}$$

First, we match the mesh points $S(\alpha_p)$ and the depth frame Dp using the Euclidean distance between their points. It is important to eliminate incorrect pairs of points. Therefore, we use two criteria to reject incorrect matches based on the distance and the direction of normal vectors of the points. If the distance between the two points is greater than a preselected threshold and the angle of their normal vectors are not substantially identical, then we eliminate the pair of points. We calculate the error E_{fit} using the weighted Euclidean distance Wp between pairs of selected points. Indeed, pairs of points with a short distance are the most important ones. That's why we use Wp weight inversely proportional to the distance between the matched points. Finally, we seek to change the coefficients vector α to find the minimum error E_{fit} using a least squares optimization. At each iteration, the error E_{fit} is recalculated. Figure 4 shows the evolution of the error on each vertex between the depth frame Dp and the average mesh $S(\alpha_p)$ at several iterations. Each depth frame contains various information about the face. A depth frame front view does not have any information on the profiles and on the sides of the nose. That is why in the figure 4 the error is greater in some parts of face (in red).

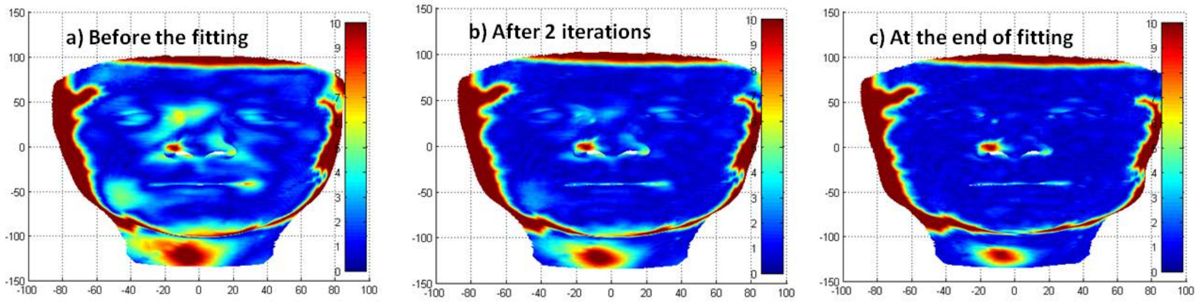

Figure 4: Evolution of error during non-rigid transformation

3.1.2 Patches Detection and Fusion on the shape

After making the fitting on each of the depth frames Dp, we obtain several structured meshes Mp. The aim of this second part is to detect the locations of the structured meshes Mp that are adequate: these places are called "patches". Then we merge these patches to create a mesh Mc.

Patches Detection: A structured mesh Mp which was created from a depth frame in right profile does not recover information of the left profile of the person as shown in Figure 5. For this reason, we want to keep only the parts of meshes that are adequate and accurate. For example, for a depth frame in right profile we want to keep the mesh patch that matches the right profile. We call "patch" all isolated points of each mesh we want to keep. Camera RGB-D captures more precisely the zones where the optical axis is perpendicular to the surface object. Therefore, we use a double condition. For a point to be preserved it must have a normal vector parallel to the optical axis of the camera and the distance between the mesh Mp and the depth frame Dp have to be smaller than a threshold. The value of this threshold is used to modify the precision of patches. Thus we get a patch for each mesh Mp. In Figure 5, we see two examples of patch detection on the 3D shape. We note that for a depth frame front view, we do not obtain all the information of the nose. Indeed, the error is large on the sides of the nose. For a frame in left profile, the error is very large to the right side of the face but little on the left side of the nose. The two depth frames of the figure 5 give different information.

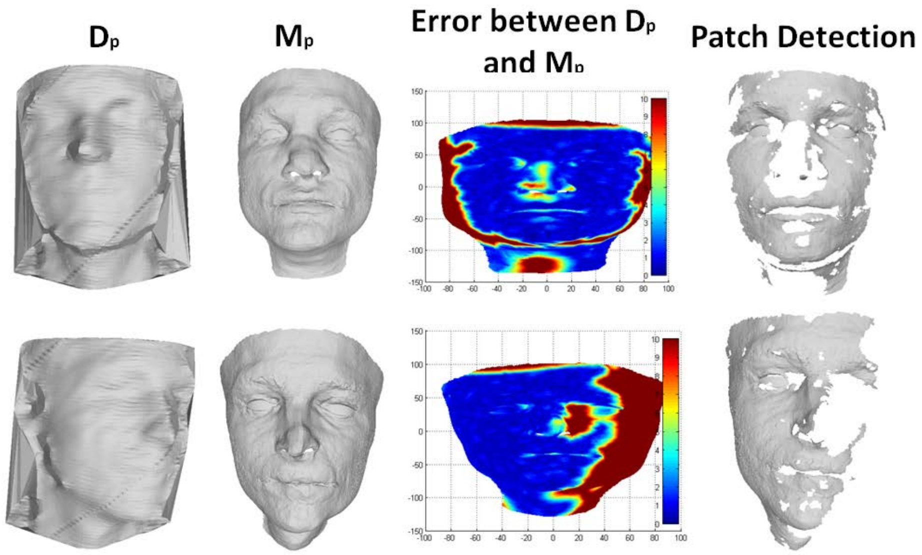

Figure 5: Example of patches detection on the shape.

Patches fusion: We want to merge the different patches we have detected to generate a complete 3D clone Mc (see Figure 2). All meshes Mp are structured. Therefore, we know the exact position of each patch on the face (eyes, forehead ...). For each point of the clone, there may be several overlapping patches (As the forehead of the face in the figure 5). That is why we make a fusion of points of these patches. We tested four types of fusion: the average, median, weighted average and robust average. For the average, we perform the average of overlapping points. For the median, we keep the midpoint. When there are not enough points (less than 3), the use of the median is not relevant. This is why we use the average value in this case. For the weighted average, the weights are the distances calculated in the step of fitting (section 3.1.1). For the fourth type of merger (robust average), we do not take into account the outliers in the calculation of the average. We eliminate the points that are away from the median value with a threshold (2mm). Figure 6 shows the result obtained with several depth frames Dp.

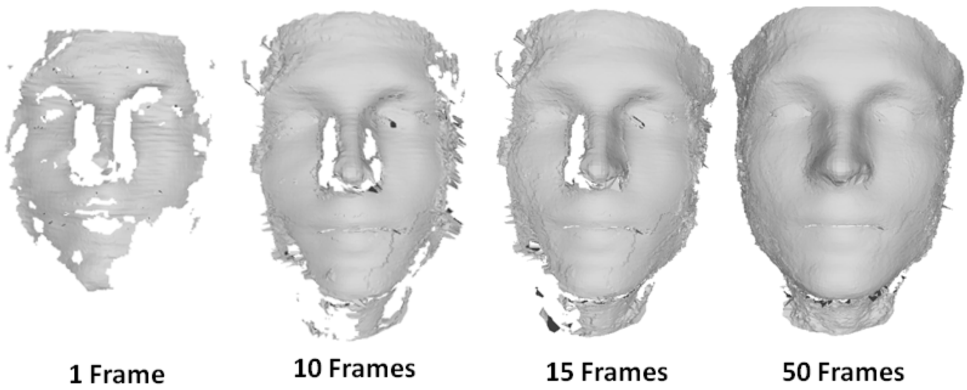

Figure 6: Patches Fusion on 3D shape (weighted average fusion)

At the end of this first step, we reconstructed the 3D shape of the face. We obtained a MC clone which will be used in the following step in order to reconstruct the texture (Figure 2).

3.2 Texture reconstruction

The second part of our method is the reconstruction of the texture. We use the same process as for the sub-section 3.1.2. This step is composed of two sub-sections: the texture mapping (3.2.1) and the patches detection and fusion on the texture (3.2.2).

3.2.1 Texture mapping

In this sub-section, we map the texture images Ip (p = 1 to n) on the structured Mc clone (Figure 2). We want several clones Tp (p = 1 to n) with **n** different textures Ip. Figure 7 shows an example of mapping for two frames, a frame profile view and frame front view. First, we align with the Mc clone each depth frame Dp using the ICP algorithm (described in paragraph 3.1.1). Camera RGB-D provides the mapping between the texture Ip and depth Dp. Then we map the textures Ip on the Mc clone using just this correspondence: for each vertex of the clone Mc, we map the texture corresponding to the closest point of the depth frame Dp. So we have several clones Tp with different textures.

3.2.3 Texture Patches Detection and Fusion

This sub-section consists of two stages: patches detection and patches fusion on the texture. We use the same procedure as for the 3D shape (see paragraph 3.1.2).

Patches Detection: We want to detect on each clone Tp, the texture patch that are adequate. Indeed, a Tp clone that was created from a texture image profile Ip does not recover the texture information on the left profile of the person as shown in Figure 7. To find out which texture points are relevant, we use the 3D shape of clones Tp and depth frames Dp. As in Section 3.1.2, we use two conditions: error distance between the clone Tp and the depth frame Dp and direction of normal vectors of their points. In Figure 7, we see two examples of patch detection on the texture. We note that for a left profile image Ip, we are not recovering the texture of the right profile. We observe that the shape error between the frame Dp and the clones Tp is relevant.

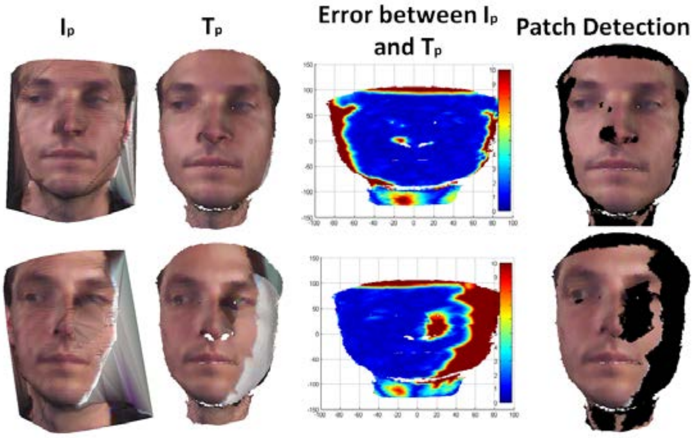

Figure 7: Example of patches detection on the texture.

Patches fusion: In this sub-step, we merge the patches detected in the previous step. We use the same method as in Section 3.1.2 to merge texture patches (RGB color of each point of the patches). We always use structured meshes Tp, which allows us to make the point to point fusion. We merge these patches for a complete facial texture. We also compare four types of fusion: average, median, weighted average and robust average. Figure 8 shows that the melting texture patches have been obtained with several images Ip using the median fusion.

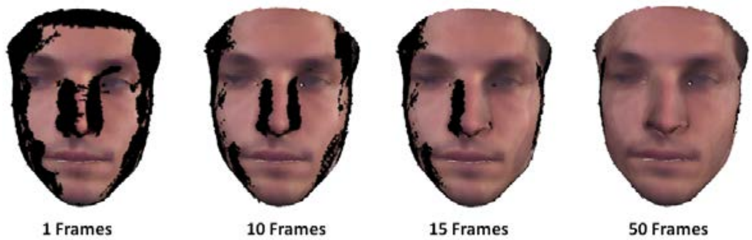

Figure 8: Patch Fusion on texture (median fusion)

Finally, our method allows reconstructing the 3D shape and texture of the face. We get a TC clone (Figure 2).

4 Experimental results

In this section, we first present the tools we have used (4.1 and 4.2) as well as our acquisition protocol (Section 4.3), then our results. We tested our method using Basel Face Model [10] and a Kinect camera. We compare our results qualitatively with other methods in the literature (section 4.5.1) and quantitatively using a ground truth (section 4.5.2).

4.1 Experimental protocol

We use a Kinect camera version 1 which is equipped with a color sensor and a depth sensor. It offers a resolution of 480 * 640 to 30 fps and it has a range at 0.5 meters. It does not work on reflective surfaces (the pupil) and in the presence of sunlight. For the fitting, we use the Basel Face Model (BFM) [10]. It was created from a training set of 200 scans of faces (100 women and 100 men). Each scan has a high resolution of 53,490 vertices (face and profile). The shape is statistically modeled by principal component analysis. Our acquisition protocol is simple and fast. Acquisitions are performed in a room with an ambient light. The subject performs a rotational movement of the head in front of the camera at 0.5 meter. He must do a neutral expression during the acquisition of data. For each person, the Kinect capture the texture Ip and the depth Dp. Our database of test consists of 6 subjects (Figure 13).

4.2 Comparisons of different fusions

For the reconstruction of the shape, we compared four methods of fusion: average, weighted mean, median and robust average. Figure 9 shows the clones obtained with the different methods for one subject. The method that uses the average does not eliminate outliers (artifacts) and the clone contains a lot of noise. The weighted average gives more importance to points of patches that are supposed to be correct, that are why it improves the results. With the median we get a better result. Indeed, one can see that there is less noise in areas without contour (cheek, forehead). However, we note that the eyebrows are more smoothed. We get the best results using the robust average. In fact, it eliminates a lot of noise (artifact) keeping details of faces: it removes the noise on the parts of the face without contour (cheek, forehead) while keeping the contour information (eyebrows ...). Indeed, it does not take into account certain items which are noisy patches in calculating the average.

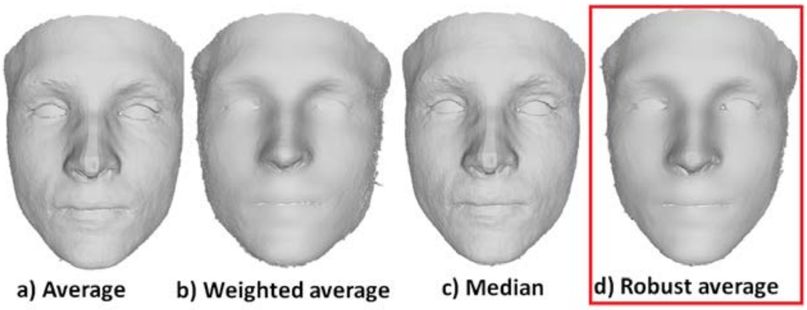

Figure 9: Comparison of different Patch Fusion on the texture

For the reconstruction of the texture, we also tested these four methods of fusion (Figure 10). We obtain a blur image of the texture when we use the average and the weighted average. The robust average slightly improves the results. Fusion with a median eliminates blur part of the texture and gives the best results. The low resolution of Kinect sensor (480 * 640) does not provide a high quality texture.

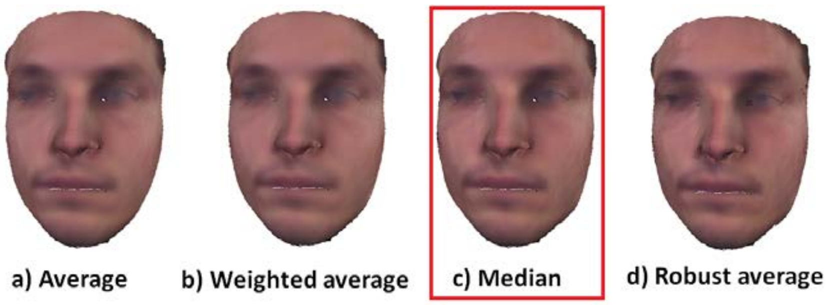

Figure 10: Comparison of several data fusion methods.

4.5 Results comparisons

We compared qualitatively (4.3.1) and quantitatively (4.3.2) our method with other methods in the literature. The qualitative comparison is used to compare the realism of the different results: we compared our results with the results of Kinect Fusion [17] and the FaceWarehouse process [2]. The FaceWarehouse process that we used consists of two steps: the merger of depth frames using Kinect Fusion and the fitting using the Basel Face Model (BFM) [10]. For fitting, we did not use the error term calculated with the feature points and the regularization term. Indeed, it is necessary that the detection of the feature points is very precise for the use of this error term is relevant. Methods for detecting the fully automatic feature points do not seem quite efficient (Active Shape Models (ASM) [23]…). Moreover, we do not use that regularization term because the algorithm converges without this term and the results obtained have fewer physical characteristics of the face. The quantitative comparison allows to know the accuracy of the results: we compared the results obtained with the FaceWarehouse process [2] and those obtained with our method with a ground truth.

4.3.1. Qualitative comparison

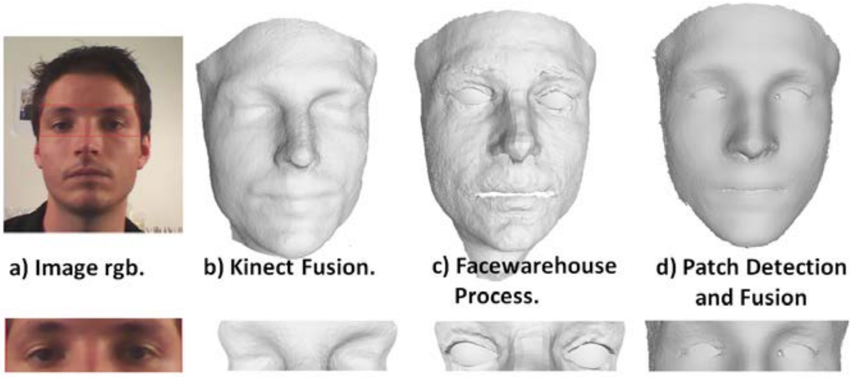

Figure 11: Qualitative comparison our results

Figure 11 shows the rendering of Kinect Fusion, FaceWarehouse process and our method on one subject. Kinect Fusion provides a clone with the specifics of the individual, but the facial features are not particularly strongly marked for instance at eye level. Ocular lobe does not appear on the 3D clone because the Kinect camera does not capture well the depth at eye level. Infrared rays are not efficient on the surfaces that reflect light (mirror, eyes ...). In addition, Kinect Fusion does not give a structured mesh. So it cannot be used directly in an application of gaze detection type [7] or facial animation for example. The FaceWarehouse process provides a structured clone where the facial features are pronounced. For example, the ocular lobe is not realistic. The clone obtained with the FaceWarehouse process has less of specifics of the individual. Indeed, Morphable Face Models are global models. In addition, they do not contain all possible forms and details of the subject's face and their learning databases are limited (200 faces for Basel Face Model). Our method is a compromise between the two previous methods. It provides that the facial features are well marked while also having more specifics of individual that a 3D clone created by FaceWarehouse process. For example, we can see that the eyes are smaller than obtained with the FaceWarehouse process. Hence, eyes of our 3D clone are more realistic.

4.3.2. Quantitative comparison

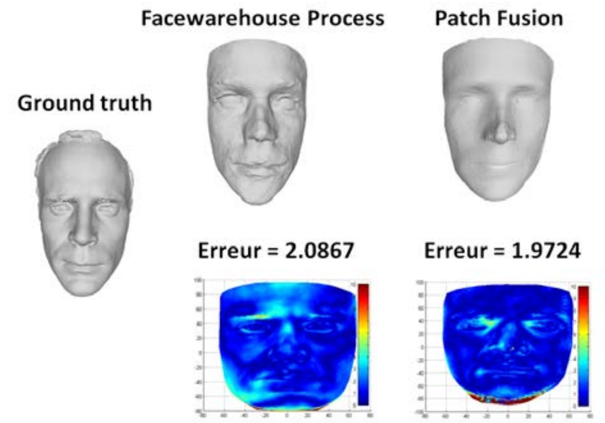

Figure 12: Quantitative comparison with ground truth

We also compared the results of our method and FaceWarehouse process with a ground truth. We do not make this comparison for our entire test database because we have the ground truth for only one subject. We did not calculate the error at eye level because the ground truth is not correct on this face area. First, we matched each point of the clone that we want to compare with the closest to the ground truth points. Then we calculated the overall error of distance between pairs of points (Figure 12). This figure shows the local error distance between each point of the two clones and the closest to the ground truth points. We can observe that the error is smaller with our method especially at the forehead and the chin. The error is larger at the level eye of 3D clone because the eyeball does not appear clearly on the ground truth. We observe that the overall error is smaller with our method (Error: 1.97) than with FaceWarehouse process (Error = 2.08). Figure 13 shows the results of our method on six subjects. It gives consistent results for different subjects.

Figure 13: Results of our method on 6 people.

5 Conclusion

Face cloning is used in the field of video games and Human-Computer Interaction. Some applications require a system with low cost and easily accessible. Our method allows cloning faces with a low-cost sensor. We use a Morphable Face Model that allows obtaining structured 3D clones. The two contributions of our method are inversion process (fitting and fusion) and the use of shape and texture patches. We reverse the process to be less dependent on the alignment and assembly error. The use of patches makes it easier to find the specifics of an individual's face. We also observed that the reconstruction of the texture of the eyes is not correct. Therefore, we want to work in the future on the improvement of the quality of the texture. Using an interpolation could improve the results obtained with our method of texture mapping. In our future work, we also want to use the super resolution methods to increase the resolution of the data Kinect and improve the quality of our results. Finally, we wish to work on the cloning of facial expressions.

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