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Color detection and shade matching in dentistry

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ABSTRACT

It is a challenge for every aesthetic dentist to determine and replicate the appearance of teeth, as it requires humility, patience and perseverance to mimic natural tooth to its closest sense and form. To provide the patient with an aesthetic restoration the dentist must consider the scientific basis of colour as well as the artistic aspect. The shade matching using digital processing techniques gives accurate results by eliminating subjective errors. In this work, the captured image is processed through MATLAB in PC and the exact shade of tooth is determined.

Keywords— *Tooth restoration, Shade detection, Image processing, Aesthetic*

1. INTRODUCTION

The vivid colours of nature infuse a dash of brilliance into the vibrant landscapes of life. These colours not only bring joy and brightness into our lives but are elemental to all forms of beauty. In the field of dentistry, it forms an important basis for achieving superior aesthetics. It is a challenge for every aesthetic dentist to determine and replicate the appearance of teeth as it requires humility, patience and perseverance to mimic nature to its closest sense and form.

Achieving an excellent aesthetic match between a dental restoration and a natural tooth is no longer considered to be elective. All dental patients expect and demand natural-looking aesthetic pleasing restorations. The restorative dentistry is determined on the basis of functional and aesthetic results. To achieve aesthetics, four basic determinants are required in sequence; viz., position, contour, texture and colour. The knowledge of the concept of colour is essential for achieving good aesthetics. Colour combination not only improves aesthetics but also makes the restoration appear natural.

The shade matching of the tooth can be accomplished in many ways. The two widely used methods are the visual selection and other instrumental methods.

Visual colour determination of a patient's tooth is the most frequently applied method in clinical dentistry. However, visual determination of shade selection has been found to be unreliable and inconsistent. Visual colour assessment is dependent on the observer's physiologic and psychologic responses to radiant energy stimulation. Inconsistencies may result from uncontrolled factors such as fatigue, ageing, emotions, lighting conditions, previous eye exposure, object and illuminant position and metamerism. There is a need for a more scientific and consistent means of shade matching in restorative dentistry.

Instrumental colour analysis, on the other hand, offers a potential advantage over visual colour determination because instrumental readings are objective, can be quantified and are more rapidly obtained. Spectrophotometers and colourimeters have been used with modifications in an attempt to overcome problems with visual shade matching in dentistry. The non-uniform colour properties of teeth involve a complex layering of tooth structure and subtle colour changes that challenge even the best instruments. Additionally, the high cost and limited utility of these instruments prevent their use in clinical dental practice.

Therefore the digital image processing techniques serve better for finding the accurate shade of the tooth.

2. PROPOSED METHOD

Feature extraction and classification are the part of an image processing system which has many applications in medical fields. The colour matching system is one of the applications which can be used for clinical dentistry. Presently, dentists use shade guides for describing tooth shades information about colour reference standard.

However, matching a suitable colour for tooth reconstruction is an important step that can make it difficult for the dentists due to the subjective factors of colour selection. Traditionally, the dentist usually selects suitable shade tabs by their naked eyes which can make the results unreliable and inconsistent.

The proposed digital image processing using MATLAB involves image acquisition, image segmentation, feature extraction, image classification for tooth shade detection.

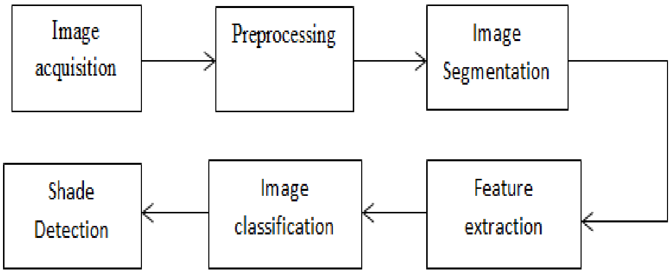

Fig. 1: Block diagram of an image processing

Colour matching system using digital images can minimize the errors and influence the aesthetic value in dental care treatment. The digital colour matching system is influenced by the same colour as the teeth images and the lighting intensity environment. The digital processing of A2 tooth shade is shown below.

2.1 Image acquisition

Image acquisition involves the collection of 50 tooth images of 16 different shades from the shade guides using digital cameras. The sample images of shade guides are collected at different lighting conditions in various environments and using different digital cameras.

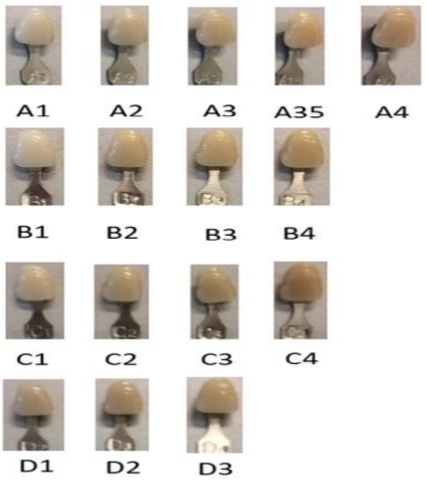

Fig. 2: Different shades of tooth

2.2 Preprocessing

The tooth image is preprocessed using a median filter to remove noise from the image.

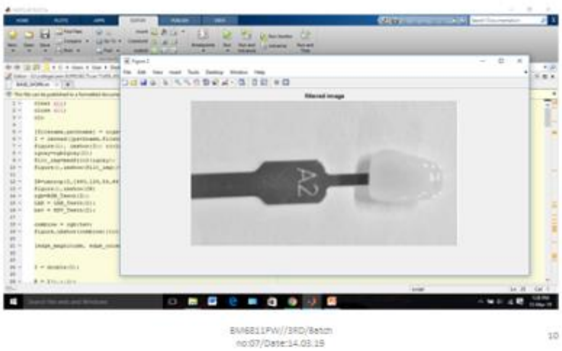

Fig. 3: Filtered image

2.3 Image segmentation

Image segmentation is done to find the region of interest, teeth and non-teeth, present in the images. After identifying those regions the data is used to detect the contours.

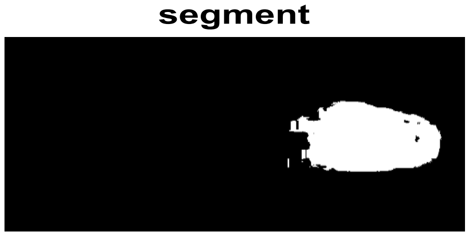

Fig. 4: Segmented image

2.4 Feature Extraction

Feature extraction involves the extraction of the desired features from the sample image. The central area of the tooth is chosen for matching the colour with the natural teeth and will be used as an effective content for shade comparison.

Therefore, providing a simple process with a high accuracy level of teeth colour matching is the main requirement in this system. Basically, the colour of the teeth is a white colour with a different value.

A colour can be produced by a combination of its basic elements which is called colour space parameter. Each colour has at least three basic elements of RGB, HSV and LAB. These are the simplest parameters which are used in the colour analysis system.

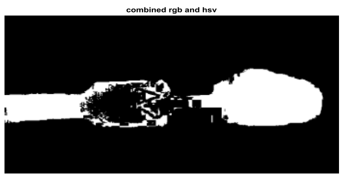

Fig. 5: Combined RGB and HSV image

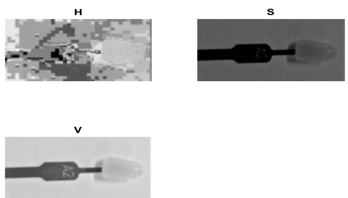

Fig. 6: Normalised HSV image

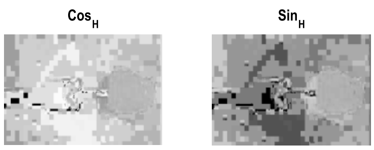

Fig. 7: Cartesian coordinates

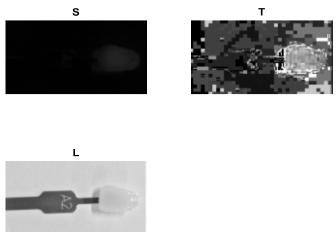

Fig. 8: Saturation, tilt and lightness image

However the colour space properties of teeth are non-uniform and involve a complex layering of tooth structure, it requires additional techniques for determining specific features of each tooth. Analysis technique using colour-moment with the simple mathematical calculation can be applied for determining the specific features based on its colour space properties.

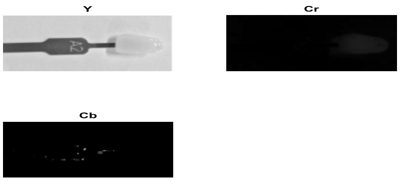

Fig. 9: LAB Colour Space

Gabor filters which are bandpass filters are used for feature extraction and texture analysis. The features of energy, correlation, area, compactness, perimeter, solidity, eccentricity are taken.

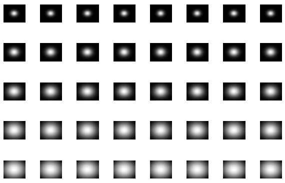

Fig. 10: Magnitude of Gabor filter

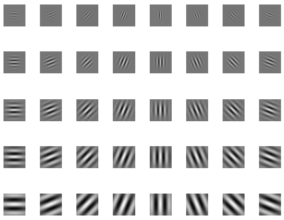

Fig. 11: Real parts of Gabor filter

2.5 Image classification

Image classification is used to identify images according to their content or feature. In order to provide suitable teeth colour, it requires an additional algorithm to classify the features based on formed features from each colour space properties.

On the other side, due to many features from each colour space based on colour moment calculation, reducing the features number is an essential step before any classification data can be performed. Principal Component analysis and K-nearest neighbour are one of the popular methods used to reduce the features for classification of the images.

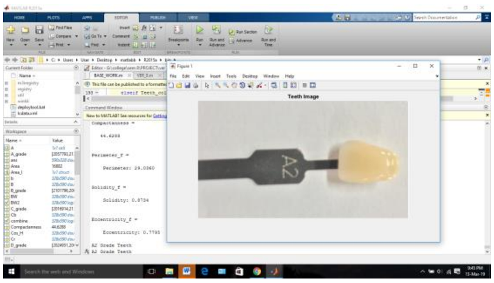

Fig. 12: Shade classification of tooth

Then the features are extracted and these features are compared and classified to detect the shade of the tooth and are displayed on the command window in MATLAB.

The features of digital tooth images taken include perimeter, eccentricity, area, compactness, solidity. The perimeter is the number of pixels in the boundary of the image. The area of the required region gives a composite shade. The compactness is defined with irregular boundaries having larger compactness with the most compact image. The perimeter_f is the number of pixels in the segmented image. The solidity_f based on the performance of existing local threshold approaches in terms of segmentation quality. The eccentricity measures the shortest length of paths with a set of values. The region of value depends on its location. The feature values of all the shades of tooth obtained are shown below.

Table 1: Feature values obtained of various shades of tooth

	PERIMETER	AREA	COMPACTNESS	PERIMETER_f	SOLIDITY_f	ECCENTRICITY
A1	1008	13211	76.9105	23.8736	0.3506	0.8722
A2	868	16882	44.6288	29.0360	0.8734	0.7795
A3.5	942	15829	56.0594	783.2010	0.9004	0.7813
A4	708	14470	34.6416	594.7420	0.9271	0.7927
B1	510	1546	168.2406	10.1970	0.2828	0.9344
B2	644	3146	131.8296	298.9910	0.6119	0.9238
B3	656	14281	30.1335	549.6860	0.9212	0.7709
C1	1046	16035	68.2330	74.4150	0.6117	0.8763
C2	3114	116442	83.2775	1.867	0.5991	0.8002
C3	1338	64354	27.8187	1.1843	0.9376	0.5472
C4	2114	189706	23.5575	2.0167	0.9925	0.8612
D1	332	2034	54.1908	261.0130	0.7743	0.7716
D2	952	15615	58.0406	17.5080	0.5831	0.8019
D3	3750	28136	499.8045	2.0991	0.4630	0.9419

3. CONCLUSION

Precision in shade matching and colour perception is vital for the aesthetic success of prostheses. Conventional shade matching technique is subjective and provides inconsistent results. However, technology based shade matching systems involving digital image processing gives accurate results in shade detection which are minimally influenced by lighting conditions and surroundings.

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