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Lossless JPEG-Huffman Model for Digital Image Compression

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ABSTRACT

The transmission of digital images has been bedevilled with limitation of storage and bandwidth capacities. One of the common strategies to resolving this limitation is to perform pre-transmission compression on the images. In this research, a lossless Joint Photography Expert Group (JPEG) and Huffman algorithms-based model for digital image compression is proposed. The lossless JPEG component of the model was used to perform Differential Pulse Coding Modulation (DPCM) on the pixels while adaptive Huffman coding was used for quality improvement and standardization. The implementation was carried out in an environment characterized by Windows 10 with Visual Basic as frontend on Personal Computer with 4 GB RAM, 500 GB ROM and 2.2 Ghz Core i3 Processor. The experimental images used for testing the algorithms were acquired from Signal and Image Processing Institute in the University of Southern California (USC-SIPI). Camera (Nikon D7000) and Geographical Information System (GIS) images were also used. Quantitative analyses of the experimental results and performance evaluation using Compression Ratio (CR), Bits per pixel (Bpp), Maximum Difference (MD), Mean Square Error (MSE), Root Mean Square Error (RMSE), Peak Signal Noise Ratio (PSNR), Average Difference (AD) and Structural Content (SC) were carried out. The analyses showed good compression rates and ratios for the proposed model. The superiority of the integrated model over some existing and related ones is also established.

Keywords: Digital image, image compression, lossless JPEG, Huffman algorithm, GIS

1 Introduction

An image is a two dimensional visual signal of any object captured by optical devices for processing, storage, transformation or transmission by computer applications. It is also described as an artefact which displays visual perception in x and y spatial coordinates based on numeric representation of a two-dimensional function *f(x,y)* over a give amplitude[1-2]. For a digital image, the spatial coordinates and the amplitude are all finite and discrete [3]. A digital image requires enormous storage due to its continuous tone and its storage can be in any form or representation with the existence of diverse conversion algorithms [4]. Digital images are classified into raster and vector. Raster images are built via a finite set of digital values, known as picture elements or pixels which represent the atomic elements and colour equivalent in the image. Electronic device-based images are notable examples of raster images. Vector images possess magnitudes and directions which are often derived from mathematical calculations. This type of images is often required when accuracy and precision are of necessity [5]. Image processing involves carrying out selected or pre-determined operations which include enhancement, restoration, segmentation, representation and compression [6-10]. Image compression is a storage optimization strategy which involves the reduction of data through

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elimination of all redundancies for acceptable quality and representation. Compression also fosters speedy transmission of images in channels with limited bandwidth [11-12]. Specifically, image compression is used in the elimination of psycho-visual, inter-pixel and coding redundancies in medical image processing, space imagery, web design, email attachment among others [13]. Image compression can be via lossy or lossless method. Lossy compression uses inexact approximations (or partial data discarding) for representing the content being encoded and it is mostly used for reduction of image data level prior to storage, handling and transmission [14-16]. The two basic lossy compression schemes are lossy transform codecs and lossy predictive codecs. While the former takes samples of images, chopped them into small segments and transform into a new and quantized space, the later is used to predict the image frame followed by quantization and coding of the error between the predicted and the real data, together with any extra information needed for reproducing the prediction [17]. This paper presents the integration of lossless JPEG and Huffman algorithms for digital image compression as solution to some of the existing problems and challenges of digital image compression. Section 2 presents the synopsis of some related works while Sections 3 and 4 present the proposed model and the experimental study respectively. The conclusion drawn from the research is presented in Section 5.

2 Related Works

Numerous research works exist for digital image compression using lossy and lossless techniques. In [18], an enhanced Lempel-Ziv-Welch (LZW) lossless compression technique for medical images is presented. The research sought improvement for some lossless compression techniques and attempted to provide a compression technique for all image formats. The resultant technique is however computationally expensive and speed deficient. The authors in [19] presented a hybrid transform technique as a solution to the problem of large storage requirements and transmission bandwidths of uncompressed images. The research used Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) based model for quality preserved compression of reconstructed images. Though experimental results on sufficiency of the model for accomplishing reasonable compression and decompression were presented, the proposed model is computationally expensive and underperforms with severally corrupted images. The authors in [15] presented a lossless image compression technique using combinatorial methods. The research focused on improving the effectiveness of Bose Chaudhuri and Hoc-quenghen (BCH) and LZW algorithms. However, the resultant algorithm is susceptible to low compression ratio and its efficiency with large data set not verified. Motivated by the need to develop a lossless decomposition algorithm which is independent of the nature and pattern of text, the authors in [20], developed a lossless text compression technique using ambigram logic and Huffman coding. The technique only focuses on text data compression without any impact on digital images. A lossless compression method based on run-length and LZW coding for digital image disk space requirement minimization is presented in [21]. The method offered an efficient means of compressing images without loss of information during transmission but its operational speed is low. A Huffman coding lossless method for image compression and decompression is presented in [22]. The method reduced the amount of disks space requirement for digital image storage but requires high speed devices for reasonable performance.

In [23], a fast and efficient lossless method for digital image compression is presented. The method implemented single bits coding, binary codes and Golomb codes for the estimation of parameters. The method attained improved compression speed but can be faulty with accidental use of contents with flat probability. The authors in [24] presented an arithmetic entropy coder based predictor model for compression of medical images. The model used context-based adaptive lossless image coding scheme for encoding and decoding in raster scan order based on prior scan lines of coded pixels for prediction and text formation. The predictor model is limited by its reliance on image smoothness assumption and mandatory selection of binary or continuous-tone mode. In [25], a lossless digital image compression technique based on simple arithmetic operations and Xilinx Field Programmable Gate Array (FPGA) is proposed. The technique is most applicable for medical and scientific images where lossy compression is not practicable. The technique requires very complex hardware for implementation and also performs poorly for low quality images. The authors in [26] presented a throughput efficient digital image compression technique that is based on Set Partitioning in Hierarchical Trees (SPIHT) algorithm. The SPIHT algorithm was used to eliminate the inherent redundancies among wavelet coefficients as well as the dynamic data structures which hinder hardware realizations. The technique successfully preserves and presents significant information by interchanging the sorting and refinement passes.

3 Proposed Model

The proposed model was motivated by the need to address some of the aforementioned limitations and its architecture is represented in the Figure 1 showing a combination of lossless JPEG and Huffman algorithms for digital image compression. In the proposed model, image grouping, pulse modulation, prediction and encoding operations are performed serially for the transformation of the input to its required output. Image grouping entails the analysis of the details of the images while pulse modulation is used to digitally represent the image by sampling it at regular intervals while each sample is made proportional to the amplitude of the modulating signal. Prediction is a pre-coding operation for examining the pixel stream.

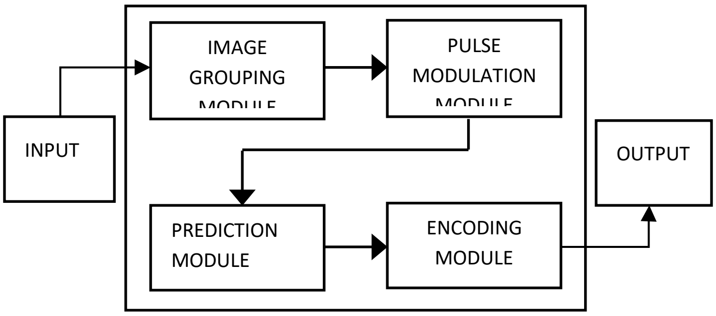

Figure 1: System Architecture

3.1 Lossless JPEG Coding Algorithm

The lossless JPEG coding process employs a simple predictive DPCM model (shown in Figure 2) in which the prediction of the sample values are based on estimation from the neighbouring pre-coded reference images in the image [27]. The model encodes the differences between the predicted samples rather than separate encoding of each sample. The basic steps of the lossless operation are shown in Figure 3. The predictor combines up to four neighbouring samples P, Q, R and S shown in the Figure 4 to produce a sample prediction value, ρ at the position labelled C based on the formula:

$$\rho = P_\alpha + Q_\beta + R_\gamma \tag{1}$$

α, β and β are the weights assigned for pixels P, Q and R respectively. The error of prediction ε, is derived as follows:

$$\varepsilon = v - \rho \tag{2}$$

v is the prediction residual (error signal) conditioned for C.

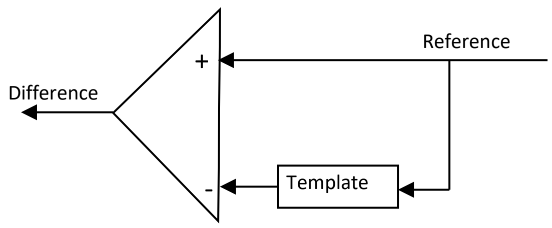

Figure 2: DPCM Encoder

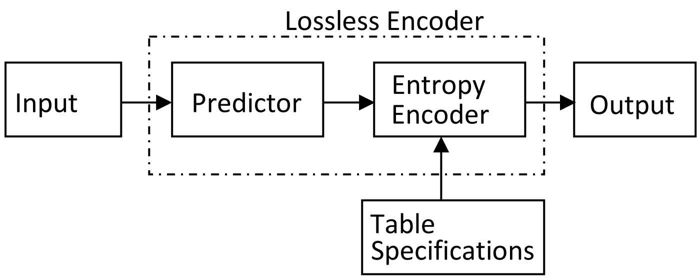

Figure 3: Steps JPEG Lossless Operation

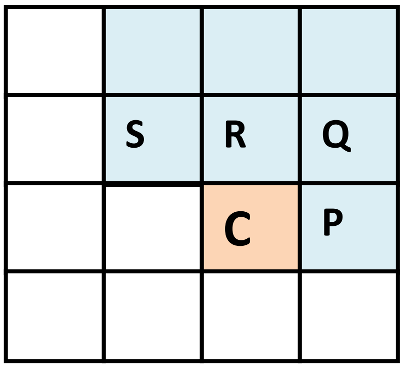

Figure 4: Prediction Process

The brightest operational value with no loss of generality for the predictive function is $P + Q + R$. When Q is the brightest, the maximum of P and R joins Q at the edge, while the minimum of P and Q joins C on the other edge, thus min (P,R) forms a good prediction. The predictive scheme presented in Table 1 is based on the following formula:

$$\rho = \begin{cases} \min\ (P,R), & if\ Q \geq \max(P,R) \\ \max\ (P,R), & if\ Q \leq \min(P,R) \\ P + R - Q, & Otherwise \end{cases} \quad (3)$$

The assigned probability distribution σ, which is the number of information (bits) contained in the image is derived from:

$$\sigma = \log(\frac{1}{\varepsilon_p}) \quad (4)$$

Table 1: Prediction Schemes

Selection-value	Prediction
0	No prediction
1	P
2	R
3	Q
4	P+R –Q
5	P+ (R – Q)/2
6	R + (P – Q)/2
7	(P + R)/2

As shown in Table 1, selection value of 0 means no prediction and it is only applicable to differential coding in the hierarchical mode of operation. Selections 1, 2 and 3 are one-dimensional predictors while selections 4, 5, 6 and 7 are two-dimensional predictors. After the prediction of all samples, the sample differences is obtained and subjected to entropy coding in a lossless fashion using Huffman coding for quality retention and speed efficiency.

3.2 Huffman Compression Algorithms

The Huffman algorithm relies on an array of unique characters along with their frequency of occurrences to produce an encoded data [28-29]. Huffman coding compression is an entropy image coding algorithm using lossless compression algorithm in which attempt is made to reduce the compositional bits of the image. Encoding of the input (source image) depends on the variable length code table. The code table C_T is uniquely derived from the estimated probability of occurrence for each possible value of the image bits as follows:

$$C_T = \sum_{k=0}^{n-1} \sigma(\varepsilon_k)p(\varepsilon_k) \quad (5)$$

ε_k is prediction residual gray level, $\sigma(\varepsilon_k)$ is the number of bits for ε_k, , $p(\varepsilon_k)$ is the probability that a pixel has a certain value (ε_k) and n is the number of grey levels contained in the image. The number of bits b is obtained using the image gray level, g as follows:

$$b = gC_T \quad (6)$$

The entropy coding value h, is obtained from:

$$h = \sum_{k=0}^{n-1} p(\varepsilon_k) \log p(\varepsilon_k) \quad (7)$$

Image compression then goes through the steps of sorting probabilities per symbol, extraction and combination of the two lowest probabilities and repetition of these two steps until only one probability remains.

3.3 Lossless JPEG-Huffman Algorithm

The Lossless JPEG-Huffman algorithm integrates the lossless JPEG and Huffman algorithms to allow further compression of the image while retaining all valuable properties. The flowchart of the visual sequence of activities of the integration is presented in Figure 5.

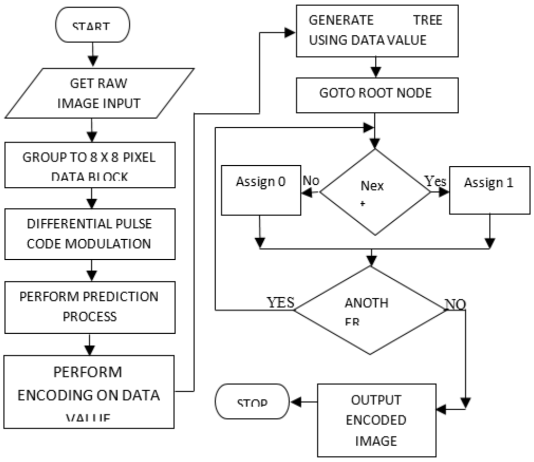

Figure 5: The flowchart of the Lossless JPEG-Huffman Compression Algorithm

Major activities include grouping of the image into 8 X 8 pixel blocks, obtaining the DPCM, performing the prediction based on the values presented in Table 1 and then encoding the data values using the Huffman encoding algorithm. This is followed by the listing of all the data values along with their frequencies as nodes. The two nodes with the lowest probabilities are taken and if there is a tie, a random selection amongst the equal frequencies is done. A new node is then constructed out of the selected node while two other nodes are developed as their children. The new node is assigned the sum of the frequencies of its children. The process of combining two nodes of lowest frequencies persists until only one node exists. 0 and 1 are then assigned to the left and right branches respectively and repetitively down the left and right sub-trees. The root to the character leaf node is transverse along the path to obtain the required value.

4 Experimental Study

The experimental study of the proposed model was carried out on a Personal Computer (PC) with 4GB RAM, 500 GB HDD and 2.2 GHz Core i3 Processor running on Windows 10 Operating System. Visual Basic, Dot Net Framework and Visual Studio served as the frontends. Digital Camera (DC) and Drone served as image capturing peripherals. The study was carried out using standard tested imagery as well as camera and geographical information system (GIS) images. The standard images from National Imagery Testing Format (NITF) and Signal and Image Processing Institute (SIPI) databases of digitized images were of various lossless formats which includes tagged images file format (TIFF), picture natural graphics (PNG) and raw binary format. These images contain some checksum values for checking the corruption levels of the images. The GIS images were obtained using a DJI Mavro Drone with the specifications presented in Table 2. The camera images were also obtained based on the specifications presented in Table 3 while the properties of twenty (20) experimental images (shown in Figure 6) from the various sources are listed in Table 4.

Table 2: Drone specifications

S/NO	Parameter	Specification
1	Size	Height: 83mm; Width: 83mm; Length: 198mm
2	Diagonal size	335mm
3	Maximum ascent speed	16feets by 5m/s
4	Maximum decent speed	9.8feets by 3m/s
5	Flight time	21 minutes
6	Maximum travel distance	13km
7	Sensor pixels	12.71m
8	Photo sensitivity	100 – 1600
9	Shutter speed	Electronic
10	Modes	Still photography
11	Exposure bracketing	Auto
12	File formats	Raw

Table 3: Camera specifications

S/NO	Parameter	Specification
1	Model	Nikon D7000
2	Resolution	23.6nm X 15.6nm
3	Sensor	16feets by 5m/s
4	pixel size	4.7µm
5	photo sensitivity	100 – 6400
6	shutter speed range	30seconds to 1/8000seconds
7	file formats	enhanced built-in raw
8	Support Mode	GPS

Table 4: Properties of selected images

Image	Dimension	Gray Level (bits/pixel)	Source	Size (kb)
Lena	512 X 512	8	NITF (Tiff)	768
Baboon	512 X 512	8	NITF (Tiff)	768
Barbara	512 X 512	8	NITF (Tiff)	768
Peppers	512 X 512	8	SIPI (Tiff)	256
Flowers	512 X 512	8	SIPI (Tiff)	768
Index	2048 X 1680	8	Camera (Nef)	1024
Index 2	512 X 512	8	Camera (Nef)	768
Index 3	2048 X 1680	8	Camera (Nef)	1024
Med 1	512 X 512	8	NITF (png)	409
Med 2	512 X 512	8	NITF (png)	511
Med 3	512 X 512	8	NITF (png)	457
Med 4	1280 X 1024	8	NITF (png)	436
Image 1	512 X 512	8	Drone (Tiff)	857
Image 2	512 X 512	8	Drone (Tiff)	771
Image 3	512 X 512	8	Drone (Tiff)	969
Image 4	512 X 512	8	Drone (Tiff)	865
Image 5	512 X 512	8	Drone (Tiff)	821
Image 6	512 X 512	8	Drone (Tiff)	901
Image 7	512 X 512	8	Drone (Tiff)	912
Image 8	512 X 512	8	Drone (Tiff)	896

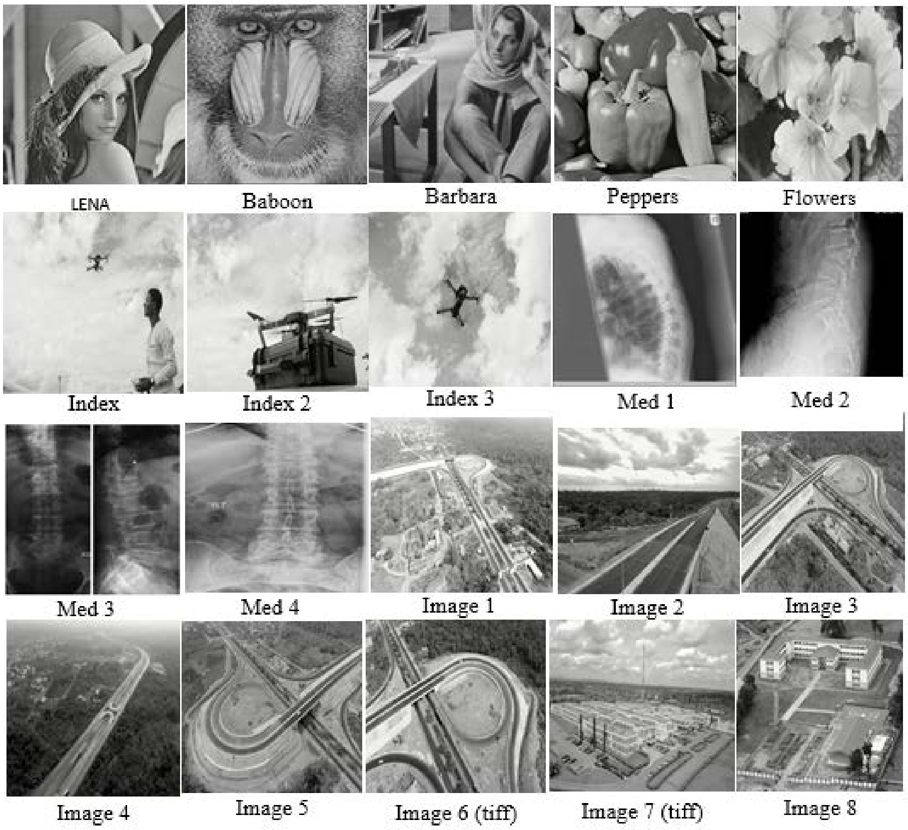

Figure 6: Experimental images

Prior to compression using lossless jpeg and Huffman algorithms, the images were first subjected to linearization which is conversion into a one-dimensional sequence with no effect on the coding schemes or frequencies. The attribute values for the adopted row-major, diagonal, snake-like and spiral scan linearization schemes are shown in Table 5.

Table 5: Comparison of different linearization schemes

Image	Row	Diagonal	Snake	Spiral	Modality
GIS	1.64	1.62	1.65	1.70	8
Camera	1.73	1.64	1.73	1.69	3
Standard tested	1.18	1.18	1.17	1.18	9

Table 6 presents the experimental results for Lossless JPEG-Huffman and Huffman algorithms on the twenty experimental images. The obtained bits per pixel (bpp) values and the compression times are also presented. Results for all the image show higher compression ratios for the integrated algorithm (Lossless JPEG-Huffman) compared to the adapted Huffman algorithm. A comparison of the bits per pixels values in Tables 4 and 6 revealed that the integrated algorithm significantly reduced the bits for every pixel in all the images. It is equally shown that the integrated model exhibit higher compression ratio and PSNR values compared to the lossless compression models for the University of Southern California and Signal and Image Processing Institute (USC-SIPI) and National Imagery Testing Formats (NITF) which have compression ratio and PSNR values of 1.1 and 40 respectively [30].

Table 6: Compression ratio for the images

Image	Size (kb)	Lossless JPEG-Huffman Algorithm (JPH)	Huffman Algorithm	JPH Bits per pixel (bpp)	Time (s)
Lena	768	1.58	1.18	5.06	1.41
Baboon	768	1.61	1.21	4.97	1.42
Barbara	768	1.46	1.29	5.48	1.41
Peppers	256	1.52	1.33	5.25	1.41
Flowers	768	1.51	1.31	5.30	1.41
Index	1024	1.74	1.19	4.61	1.80
Index 2	768	1.82	1.41	4.38	1.58
Index 3	1024	1.97	1.23	4.06	1.78
Med 1	409	1.42	1.48	5.63	1.41
Med 2	511	1.39	1.17	5.76	1.41
Med 3	457	1.42	1.13	5.64	1.41
Med 4	436	1.49	1.19	5.38	1.41
Image 1	857	1.61	1.31	4.97	1.74
Image 2	771	1.59	1.28	5.03	1.76
Image 3	969	1.39	1.13	5.75	1.76
Image 4	865	1.46	1.24	5.48	1.74
Image 5	821	1.46	1.27	5.48	1.76
Image 6	901	1.41	1.21	5.67	1.76
Image 7	912	1.43	1.15	5.60	1.76
Image 8	896	1.38	1.13	5.80	1.76

The charts of the pre and post-compression MD, MSE, RMSE, PSNR, AD and SC values are presented in Figures 7 to 12. Visual inspection of the charts reveals smaller post-compression values for all the metrics. This established the significant contribution of the integrated algorithm in bit size reduction and quality improvement of digital images.

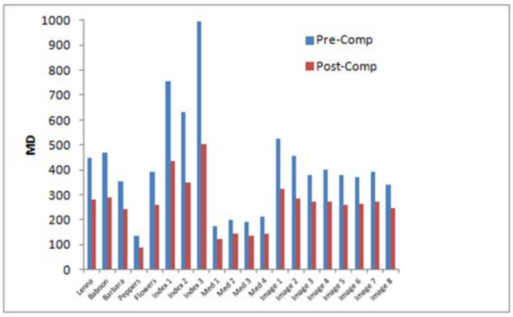

Figure 7: Pre and Post Compression MD values

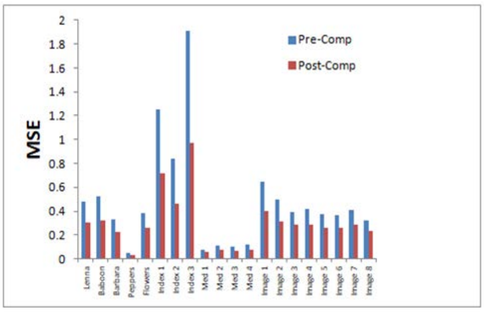

Figure 8: Pre and Post Compression MSE values

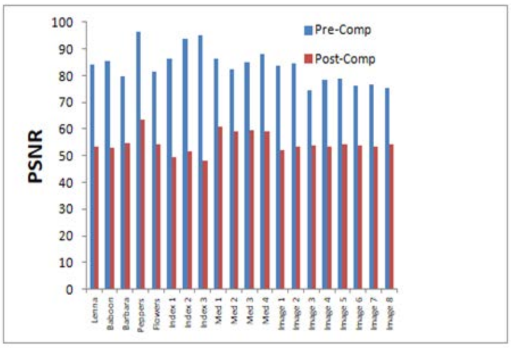

Figure 9: Pre and Post Compression PSNR values

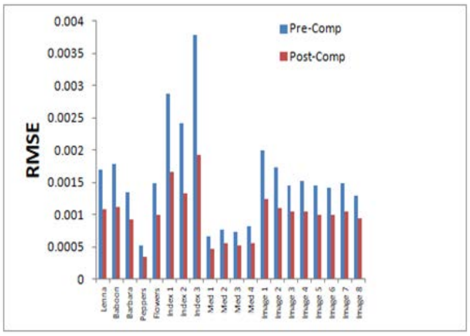

Figure 10: Pre and Post Compression RMSE values

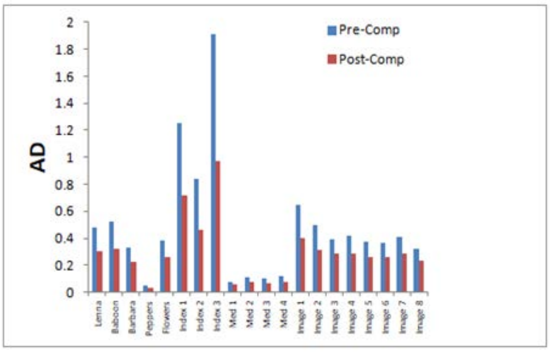

Figure 11: Pre and Post Compression AD values

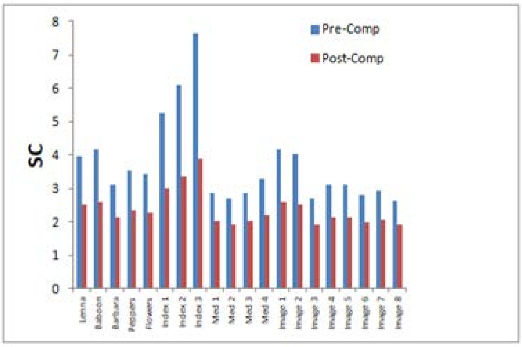

Figure 12: Pre and Post Compression PSNR values

5 Conclusion

The integration of lossless JPEG and Huffman algorithms for digital image compression had been presented. The integrated model was implemented and tested with digital images of different sizes, sources and formats. The performance of the proposed model was investigated based on image of different sizes and qualities. Experimental values obtained for standard metrics such as maximum difference, mean square error, peak signal to noise ratio, average difference and structural content were also used to establish the model's practical functions and suitability. The analyses of the obtained experimental values show that the integrated model exhibit superior compression ratios and metric values compared to the standard lossless compression models for the University of Southern California, Signal and Image Processing Institute (USC-SIPI) and National Imagery Testing Formats (NITF) which have standard compression ratio of 1.1 and PSNR of 40. The suitability of the integrated model for alleviating the problems of bit and size overflow as well as lengthened transmission time through significant reduction of the bit size and redundancies was also established. Further research focuses on combination of other lossless compression algorithms for attaining much more improved compressions. Focus will also be on the compression of 3-D images.

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Distortion Invariant Object Recognition Based on Mach-Zehnder Joint Transform Correlation in YIQ Colour Space

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ABSTRACT

We investigate the YIQ colour space in conjunction with average cross correlation optimization algorithm to design the reference function for pattern recognition on various views of the interested colour object. Joint transform correlation is devoted for recognition of colour targets. The reference function for each color channel is trained with true class images rotated in-plane at 2 degrees intervals between -14 degrees and 14 degrees. Results indicates the feasibility of our proposed method.

Keywords: Joint transform correlation; Colour pattern recognition; YIQ colour space.

1 Introduction

VanderLugt correlator (VLC) [1] and the joint transform correlator (JTC) [2] have already been two well known optical correlators. VLC was proposed for comparing two signals by utilising the Fourier transforming properties of a lens. This is the most commonly used type of correlator, but perhaps the most complex and sensitive to build, due to its strict alignment criteria. In 1966, Weaver and Goodman introduced the JTC for pattern recognition application. A few years later, LCD based JTC [3] proposed by Yu and Lu became an attractive tool for pattern recognition. Since then, the JTC configuration has received increased attention because the JTC does not require a complex filter in the Fourier plane like the VLC. However, the classical JTC yields poor correlation output where a large zero-order term (also called DC term) dominates the correlation outputs. The DC term is the sum of each auto-correlation of the reference image and the target image at the output of correlation plane. The existence of the DC term will influence the performance, therefore the removal of the nonzero-order term is of great importance.

To deal with the DC term, Lu et al. [4] adoped phase-shifting technique to design a nonzero- order JTC (N0JTC) and Li et al. [6] used the joint transform power spectrum (JTPS) subtraction strategy to realize the N0JTC. The Mach-Zehnder JTC (MZJTC) [6-8] can remove the zero-order term in only one step directly without storing the Fourier spectra of both the reference and target images beforehand. Later, Chen et al. [9,10] adopted constraint optimization based on Lagrangian method to yield a sharp correlation peak.

On the other hand, colour provides much more information than intensity. The RGB colour space is the dominant colour space and the most frequently used. However, empirical evidence suggests that distances in colour spaces such as YIQ space correspond to perceptual colour differences more closely than do distances in RGB space. We will take advantage of this feature for colour pattern recognition. Our technique involves monochrome lasers for illumination and therefore, requires the color components (Y, I and Q) to be converted into gray level.

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2 Analysis

Color plays a role in object recognition. A color space is an arrangement of a coordinate system where each color is specified by a single point. RGB color space has been most frequently used. It consists of the red, green and blue respectively. However, RGB color model is not the most suitable color model on many applications. In this paper, the color seperation to design the reference function (or template) is based on YIQ color space, which stores color information in three channels, just like RGB. Y stands for luminance that represents the achromatic (black and white) image without any color. I and Q convey colour information. I is deviations from orange-luminance to cyan-luminance and Q is deviations from purple-luminance to chartreuse–luminance. Moreover, the optoelectronic system is based on a MZJTC structure [8]. It is consisted of one laser, one spatial filter, one collimated lens (CL), 3 beam splitters (BSs), 3 polarizing beam splitters (PBSs), 3 Fourier lenses (FLs), 3 reflective liquid spatial light modulators (RLCSLMs), 3 charge coupled device (CCD) cameras, 1 electronic subtractor (ES) which is used for removing the zero-order term at the final output, and 1 computer for controlling the whole system. Besides, there are 1 half wave plate (HWP) and 1 quarter wave plate (QWP) in front of each of 3 RLCSLMs. The MZJTC structure is based on the Mach-Zehnder interferometer technique with Stokes relationships. The difference between conventional N0JTC and MZJTC is that the MZJTC structure needs only one step to remove the zero-order term. The processes are presented as follows.

First, 3 colour channels of the test colour image are jointly displayed in grayscale at one reflective liquid crystal spatial light modulator (RLCSLM). Similarly, 3 colour channel of the test colour image are also displayed in grayscale at another RLCSLM. The target on the first RLCSLM is illuminated and Fourier optically transformed. After passing through the beam splitter, the irradiance of transmitted and reflected Fourier spectrum is respectively detected by 2 CCDs in the Fourier frequency domain. Then, the difference of joint Fourier power spectrum between 2 CCDs is displayed at the third RLCSLM, such that the zero-order term will be subsequently removed at the output. Finally, the third CCD captures another Fouier transform spectrum of the difference. The output contains the overlapping of each cross-correlation of the reference channel and the target channel. More detailed analysis of MZJTC can be found in the literature [6-8].

For each of Y, I, Q channels, we minimize the average cross correlation energy by using the Lagrange multipliers method to suppress sidelobes and maintain the correlation peak at a specified height. This results in a closed form solution in the frequency domain. It is a column vector, which needs to be re-ordered back into a 2-D array, and then to be inverse Fourier transformed to the space domain.

To evaluate the recognition capability, some measurement criteria [13] including correlation peak intensity (CPI) and peak-to-correlation energy (PCE) are utilized. CPI is the cross-correlation peak intensity at the correlation output plane. PCE is defined as the energy of the peak correlation normalized to the total energy of the cross correlation plane.

3 Result

We use the image of one colourful insect as the basic pattern of the target. The size of the target is $64 \times 64 \times 3$ pixels with intensity values in the range [0,1]. Y, I and Q channels are separated. For the purpose of comparison, another insect is selected as the nontarget. These two images are shown in Figure 1. For simplicity, We rotate these 2 objects in plane from -14° to 14°, and select patterns 2° apart. Totally there are 15 rotationally distorted patterns per object used as the training set for each colour channel. Next, for each training set, we utilize the method of Lagrange multipliers for cross correlation optimization to obtain the reference template.

Figure 1: Target (left) and nontarget (right)

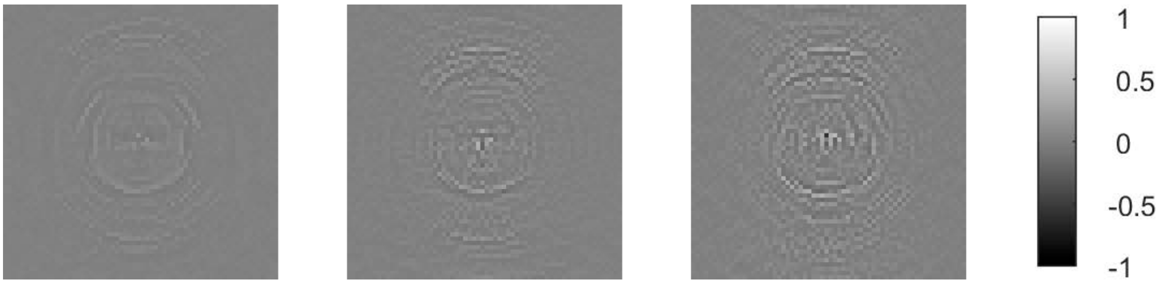

Figure 2: Y, I, Q reference functions for the target

Figure 2 shows respectively the synthesized reference function of Y, I, Q channels from left to right. To cope with the optical requirement, the value of the grayscale is confined between -1 to 1, as illustrated by the dynamic range on the right-hand side of the figure. It is worth noting that the CPI is designed to be the same for all training targets.

In Figure 3, the left image shows 3 color channels from one target displayed on one RLCSLM, while the right image shows 3 calculated reference functions displayed on another RLCSLM. The overall size of the joint image on each RLCSLM is 512 × 512 pixels. In Figure 4, the left image shows 3 color channels from one non-target displayed on one RLCSLM, while the right image shows calculated reference functions displayed on another RLCSLM.

The overall rotation invariance result is obtained, as illustrated in Figure 5. The CPI curve versus the rotation angle for the target as well as for the nontarget are shown in for the purpose of comparison. These 2 curves are seperated considerably. To determine whether the object under test is the target, we can set a threshold value of correlation peak, above which the input can be treated as a target and below which it is a non-target. Figure 6 illustrates three-dimensional plots of the output correlation intensity around the region of interest, where addition of desired cross correlations between the reference and the colour channel from all 3 channels occurs. Both the target and nontarget are 0° rotated. As expected, the correlation peak is very narrow. Sidelobes suppression is achieved. High correlation peak corresponds to the correct pattern, whereas low correlation profile is observed for the nontarget. We obtain recognition of target and discrimination of nontarget. To see how much YIQ space improves, PCE curve for RGB colour space is also plotted in figure 7. The curve is lower than that for YIQ curve at each rotation angle of the target. The main reason is that, in most cases, when compared with RGB channels, YIQ channels are less correlated with other. This explains why the correlation profile is sharper for YIQ colour space. This reveals that by converting the RGB representation to the YIQ representation, the resulting three channels are less correlated and give better performance.

Figure 3: Left: 3 color channels from one target displayed on one RLCSLM; right: 3 calculated reference functions displayed on another RLCSLM.

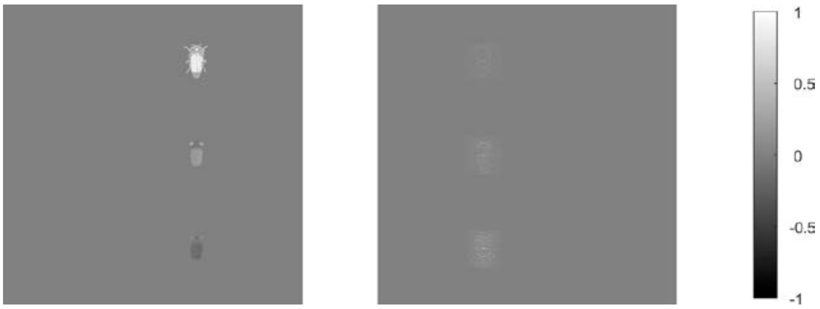

Figure 4: Left: 3 color channels from one non-target displayed on one RLCSLM; right: 3 calculated reference functions displayed on another RLCSLM.

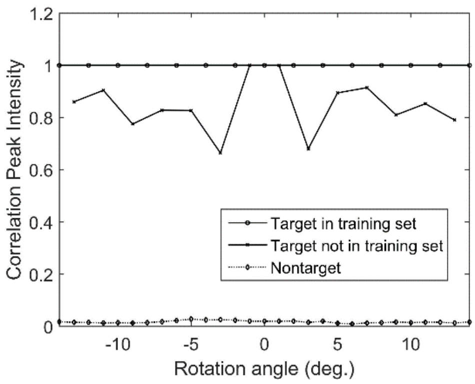

Figure 5: CPI versus rotation angle

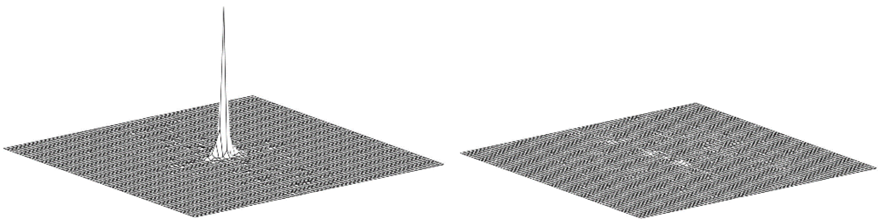

Figure 6: Example of correlation output for target (left) and nontarget (right).

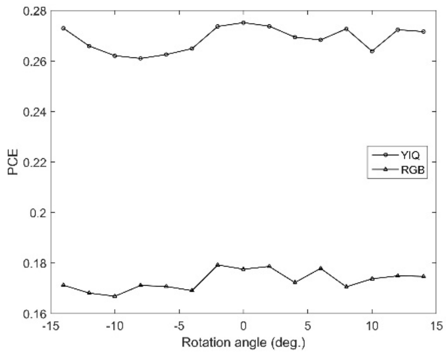

Figure 7: Comparison of the PCE between YIQ and RGB colour spaces as the target rotates.

4 Conclusion

In this research, we have provided an analysis of the performance of YIQ colour space together with average cross correlation optimization algorithm for pattern recognition on MZJTC. Comparison between YIQ and RGB colour spaces has been evaluated in terms of PCE. The improvement is remarkable. Numerical result shows that YIQ space outperforms conventional RGB space. It is exactly what we expected to see. This work is expected to provide valuable data for further research.

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Consonant Deletion in the Speech of English-Platoid Bilinguals

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ABSTRACT

This paper, which examines consonant deletion in the speech of English-Platoid bilinguals, is in the domain of articulatory phonetics. When English words end in two or three consonants, speakers of English who are native speakers of Platoid languages usually delete consonants word finally during articulation. This has been of deep interest to the researcher, and therefore decides to investigate the phenomenon that leads to this incidence as a way of proffering a linguistic explanation to it. To do this, a total of twenty-two sentences containing words that end in two or three consonants were used as data elicitation technique from some English-Platoid bilinguals. These words were noted by the researcher during informal daily conversations at different occasions. The words whose consonants got deleted at the word final position were transcribed phonetically for purposes of clarity. The second part of the data constitutes the elicitation of six words of common nouns each from ten indigenous Platoid languages. Since the focus is on consonant deletion, few consonant systems of these languages were also presented. This is so done with a view to discovering whether there is evidence of consonant cluster in those languages or not, especially at word final position in order for the researcher to pin down the factor responsible for the deletion. From there, the study concludes that there is no evidence of consonant cluster at word-final positions in Platoid languages, and where it does, it only exists as digraph orthographically, as in: *shīk-bīsh* 'sin', *kàt-ɗang* 'if' (Mwaghavul); *kámbọng* 'cocoyam' (Ron); *ìshọsh* 'honey bee', *nànámàng* 'girls' (Afizere); *ìkpáng* 'plate', *ǹding* 'water' (Tarok), etc.

Key words: Platoid, consonant deletion, bilingual.

1 Introduction

Throughout the researcher's time of sojourn in Jos, the Plateau State capital (for both undergraduate and graduate studies), this incidence of consonant deletion has been a great drawer of my attention. This study, which is on consonant deletion in the speech of English-Platoid bilinguals, belongs to the domain of articulatory phonetics, and it is embarked upon to carefully scrutinise the circumstance that necessitates the deletion.

The Platoid of north-central Nigeria is one of the major branches of the New Benue-Congo family. Blench (2008:1) reports that among the many language groups represented in Nigeria, one of the largest and most complex is the Platoid languages, representing some 50-120 languages, depending on how inclusive the term is taken to be. The Platoid is believed to be a larger and highly complex branch, extending across the northern boundary of the Benue-Congo and subdividing into Kainji, which includes languages such as Kambari, spoken near Lake Kainji, and Central Platoid, which in turn divides into

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Plateau, containing many of the small languages spoken around Jos, and in Southern part of Kaduna State, Tarokoid, including Tarok and other languages east of Jos (Williamson, 1987:18 & Ogbulogo 2013:12). Blench (2008:2) further notes that Tarokoid is part of Plateau (or Platoid), albeit a primary branching and similarities with Jukunoid are due to proximity, and that membership of Tarokoid should be restricted to Tarok, Pe, Yankam and Sur (also known as Tapshin).

Linguistically, Plateau State has over forty ethno-linguistic groups but no single group is large enough to claim majority position. Some of the indigenous tribes in the State include: Afizere, Amo, Anaguta, Angas, Aten, Berom, Bogghom, Buji, Challa, Chip, Fier, Gashish, Goemai, Irigwe, Jarawa, Jukun, Kwagalak, Kwalla, Meryang, Miship, Montol, Mushere, Mupum, Mwaghavul, Ngas, Piapung, Pyem, Ron, Kulere, Tarok, Youm, etc. Each ethnic group has its own distinct language, but as with the rest of the country, English is the official language in Plateau State, although Hausa has gained acceptability as a medium of communication (http://www.informationng.com).

2 Statement of the Research Problem

Prior to the time of this research, there has been little or no investigative study that could lead to a valid statement or conclusion on why English-Platoid bilinguals (especially indigenes of Plateau State, North-Central Nigeria) delete the last consonant sound in a cluster of consonants during speech or utterance. Could it be English-Platoid bilinguals have no consonant cluster both at the onset and coda, or they have at the onset and none at the coda or vice-versa? What reason could be advanced for the consonant deletion at the coda? This in itself is a wide knowledge gap that has been waiting to be filled. In view of this, the researcher was moved or motivated by strong inner drive as well as deep passion to carry out this study with a view to filling this knowledge gap.

3 Literature Review

Our review of literature here will focus mainly on the important concepts that constitute the topic or title of this research, which are consonant deletion and bilingual. Besides these, the review will include empirical works done by other language scholars over the years that are related to the current research.

3.1 Conceptual Review

Deletion is the art of removing something that has been written or printed. Consonant deletion, therefore, means eliminating a consonant sound in a word. In the light of this, Rippon (2017:4) states that consonant deletion takes place when one or two consonant sounds are omitted from the beginning, middle or end of words. In Akan language, Adomako (2008:32) reveals that deletion of consonants usually occurs in two main ways, mostly in the word-final and rarely in the word-medial positions. Either, the C1 of the cluster is deleted or the C2 of the cluster is deleted. Similarly, Rashidi & Shokrollahi (2010:138) observe from their study on the Shirazi dialect of Persian that glottal consonants /h/ and /?/ are deleted in all phonetically weak positions: coda-position (word-finally), intervocalic position and in clusters but they are retained word-initially. In an attempt to explain the concept of deletion, Ovu (2013:10) points out that pronouncing the words such as *psychology*, *pseudonym*, *psalm*, *psychiatrics*, *psyche*, etc. with the initial /p/ sound would apparently result in a deviant consonant cluster in English. This is because at the onset, English cannot allow a combination of plosive + fricative. Thus, faced by this dilemma, English speakers usually drop or delete the consonant sound /p/ while retaining that of /s/ in their pronunciation. At word medially and finally, he further posits that the consonant sound /b/ is usually silent in two main areas, namely where it combines with the sound /t/ and where it combines with that of /m/, as exemplified in the following words: su**b**tle, dou**b**t, de**b**t, plum**b**, clim**b**, dum**b**, tom**b**, bom**b**, etc. adding that the reason for this is the peculiarity of English phonotactics which does not allow a sequence of /mb/ or /bm/ sounds to form a cluster whether word initially or finally. However, considering the focus of our study, this is not the case at all with the native speakers of the Platoid languages who speak English as their L2. Their deletion of consonants word-finally in speech is never attributable to the phonotactics of English. This, indeed, is the driving force behind this study, that is, to lay bare before the reader what actually is responsible for this phenomenon during articulation.

According to Crystal (1991:53), the general sense of the term bilingual refers to a person who can speak two languages. However, this is dependent on several factors. Defining who a bilingual is reflects assumptions about the degree of proficiency people must achieve before they qualify as bilinguals (whether comparable to a monolingual native-speaker, or something less than this, even to the extent of minimal knowledge of a second language). Similarly, Bloomfield (1933) as cited in Liddicoat (1991:2) defines a bilingual as one who has 'native-like' control of two languages. But this definition excludes many people who speak more than one language but do not have 'native-like' control of one or both of their languages. In addition, Franson (2011:1) says that the term bilingual is used to describe a learner who uses two or more languages to communicate. However, defining who a bilingual is ranges from a minimal proficiency in two languages, to an advanced level of proficiency which allows the speaker to function and appear as a native-like speaker of two languages; a person may describe himself as a bilingual but may mean only the ability to converse and communicate orally; others may be proficient in reading in two or more languages; a person may be a bilingual by virtue of having grown up learning and using two languages simultaneously, or s/he may become a bilingual by learning a second language sometime after his/her first language. So, to be a bilingual means different things to different people. Irrespective of the difficulty in defining who a bilingual is (or factors determining who a bilingual is), our focus in this research is to investigate how native speakers of the Platoid languages (within Jos, Plateau State) who also speak English as a second language, delete consonants, especially at word-final positions during articulation.

3.2 Empirical Review

Empirically, studies on a subject such as this are not very common in Nigeria, and perhaps, other parts of the world. However, few related researches have been conducted by some language scholars both home and abroad, even though they are not linked to a particular group of people like ours. They are as follows:

Davidson (2004) embarked on research entitled *Schwa Elision in Fast Speech: Segmental Deletion or Gestural Overlap?* Through intuition, the researcher observed phonological analyses attributing schwa elision to across-the-board segmental deletion, and phonetic accounts proposing that elision, being characterised as gestural overlap have been restricted to very few sequence types. In the method, 28 different [#CəC-] sequences were examined and 9 participants (6 males and 3 females) were used to define appropriate acoustic criteria for elision, to establish whether elision is a deletion process or the endpoint of a continuum of increasing overlap, and to discover whether elision rates vary for individual speakers. The result of the study revealed that the acoustic patterns for elision are consistent with an overlap account. Individual speakers differ as to whether they increase elision only at faster speech rates, or elide regardless of rate.

Furthermore, Adomako (2008) conducted a research titled *Vowel Epenthesis and Consonant Deletion in Loanwords: A Study of Akan.* The aim of this study was to shed light on the loanword adoption phenomenon in Akan, a majority language spoken in the West African country of Ghana. Foreign words with sequences of obstruents as in /st/, /sp/, /pl/, /sk/, etc. and word-final obstruents adopted into the language have to go through some repair processes to conform to the structural well-formedness requirement in the native grammar. The two main repair strategies that apply to these illicit foreign words include vowel epenthesis and consonant deletion. As for the methodology, the database, which served as the basis of this study, was a collection of loanword corpus from the two of Akan dialects: Fante and Twi. An initial set of loanword corpus of over 200 words was collected on the field from two sets of informants: the monolingual and the bilingual speakers at two different locations. The monolingual speakers are predominantly illiterates, i.e. they do not have any formal education, while the bilingual speakers, on the other hand, are either literates or semi-literates, i.e. the members constituting this group have, at least, basic formal education. The finding of the research showed that differences exist between the two dialects, and that they have more in common than they differ in terms of how they adopt foreign words.

Moreover, Gerlach (2010) undertook a study titled *The Acquisition of Consonant Feature Sequences: Harmony, Metathesis and Deletion Patterns in Phonological Development*. The researcher, in this research, examines three processes affecting consonants in child speech: harmony (long-distance assimilation) involving major place features as in coat [koʊk]; long-distance metathesis as in cup [pʌk]; and initial consonant deletion as in fish [ɪʃ]. These processes are unattested in adult phonology, leading to proposals for child-specific constraints. Initial consonant deletion in particular, is a little-understood phenomenon thought to be idiosyncratic but initial consonant deletion as reported in eight languages reveals systematic deletion patterns affecting continuants and sequences of different consonants. From the methodology, the data used displayed evidence for both constraint demotion and promotion in learning, as well as distinct roles for two types of faithfulness constraints: one mandates the preservation of non-default features that are specified in the underlying representation, while the other evaluates identity of a correspondent segment to any non-default feature associated with a segment.

Lastly, Ovu (2015) carried out a study titled *Consonant Deletion in English: Phonotactic Explications and Implications for Teaching Spelling in an ESL Situation*. The study considers consonant deletion as one of the major contributors to the irregularities in the spelling system of English, and accounts for a great number of pronunciation errors committed by the L2 users of English. The main thrust of this paper is to show that consonant deletion is not often haphazardly done in English but rather it is systematic and governed by some rules which obtain from the phonemic system of the language. These rules are known as phonotactic rules, and their non-observance would not only result in erroneous pronunciation but could portray a speaker as being careless and at times incompetent in using the language – a situation that may be very embarrassing. Focusing on the phonotactic basis of consonant deletion, the paper attempted to bridge this yawning gap by providing some insights into some simple but effective ways of improving the ESL users’ spelling ability and boosting their confidence when communicating with native speakers of English or before an international audience.

4 Theoretical Framework

This research is hinged on Firth’s theory of descriptive linguistics of 1951. Originally, the term descriptive was coined to express the distinction between historical or comparative linguistics, which dominated much of 19th century linguistics, and the emerging structuralist paradigm with its emphasis on the notion of a synchronic system. Firth, as echoed by Love (1986:31) maintains that the business of linguistics is to describe language. She further reports that Firth takes linguistics to be primarily concerned with the speech-events themselves, and dealing with speech-events will involve the systematic deployment of analytical constructs and categories, which may in practice turn out to be rather similar to the constructs and categories involved in the analysis of abstract systems underlying speech-events. In a clearer perspective, descriptive linguistics is a study of a language, its structure, and its rules as they are used in daily life by its speakers from all walks of life, including standard and nonstandard varieties, that is, descriptive linguistics describes the language, its structure, and the syntactic rules that govern sentence and phrase constructions. Importantly, the concept of descriptive analysis is, in principle, applicable to any set of data, provided that these data represent the actual usage of a language under study at a given time in a given speech community.

From the foregoing, it is obvious that descriptive theory perfectly fits into this study. This is because in this research, we will describe vividly how native speakers of Platoid languages who speak English as L2 delete consonants word-finally during articulation. And of course, such description can never be complete, valid and reliable without the use of data. Data is considered as a tool with which linguists analyse or describe any language or its use by a particular speech community scientifically with a view to arriving at valid conclusions.

5 Methodology

This study, which investigates consonant deletion in the speech of English-Platoid bilinguals, is a qualitative one. Amenorvi (2011:62) quotes Shank (2002) as saying that a qualitative study can be defined as a form of systematic empirical enquiry into meaning. Systematic here means that the study should be well planned and organised, and empirical here means that such an enquiry should be grounded in the world of experience. In line with this, the researcher has experientially witnessed how native speakers of Platoid languages who speak English as second language do delete consonants at word-final positions during articulation, an incidence which informed the present study. Furthermore, as cited in Amenorvi (2011:62), Fraenkel and Norman (2002) as well as Reinard (1998) outline the major characteristics of a qualitative study, which include: “qualitative data, flexible design, naturalistic enquiry, personal contact and insight, inductive analysis and holistic perspective”. In view of this, a total of twenty-two sentences containing words whose word-final consonants were deleted by native speakers of Platoid languages, who speak English as second language was used as the first part of data collected for this study. For purposes of clarity and specificity, the words whose final consonants were deleted were transcribed phonetically. In addition, six words each were elicited from ten Platoid indigenous languages along with few of their consonant systems because some of the languages are yet to be developed. And that forms the second part of the data. This is used as a tool through which the researcher is enabled to pin down the factor responsible for this phenomenon among English-Platoid bilinguals. All these were done using personal contact, informal and phone conversations technique, which were carefully noted as well as personal intuition of the researcher, having dwelt among them for about eight years.

6 Presentation of Data, Analysis/Discussion

As mentioned earlier on in our methodology, a total of twenty-two sentences containing words whose word-final consonants were deleted by English-Platoid bilinguals is used as the first part of data collected for this study, while six words each were elicited from ten Platoid indigenous languages, and this forms the second part of the data. This is done with the sole aim of boosting our analysis and to make us reach a valid and cogent conclusion. We therefore present the data as follows:

(A) 1. The *studen* is sick. [*stju:dən*] instead of /**stju:dənt**/.

2. Please do not stop my *movemen*. [*mu:v.mən*] instead of /**mu:v.mənt**/.

3. God always keeps *covenan*. [kʌv.ən.ən] instead of /**kʌv.ən.ənt**/.

4. Our *governmen* has failed. [*gʌvən.men*] instead of /**gʌvən.ment**/.

5. Let us go and *plan* cassava. [*plɑ:n*] instead of /**plɑ:nt**/.

6. Please *repen* of your sin today. [*rɪpen*] instead of **/rɪpent**/.

7. I had *lef* before you came. [*lef*] instead of /**left**/.

8. INEC is planning to *shif* the 2019 general elections. [*ʃɪf*] instead of /**ʃɪft**/.

9. The *shaf* of his car had been removed. [*ʃɑ:f*] instead of /**ʃɑ:ft**/.

10. What is my *faul* in this matter? [*fɔ:l*] instead of /**fɔ:lt**/.

11. Please let the *secon* person come in. [*sekən*] instead of /**sekənd**/.

12. It is very *col* in Jos at the moment. [*kəʊl*] instead of /**kəʊld**/.

13. Our meeting today will *hol* by 2:00 pm. [*həʊl*] instead of /**həʊld**/.

14. Please *fol* the bed sheet gently. [*fəʊl*] instead of /**fəʊld**/.

15. The *conduc* of the general elections was peaceful. [*kɒndʌk*] instead of /**kɒndʌkt**/.

16. *Aspec* of the Theory of Syntax. [*æspek*] instead of /**æspekt**/.

17. The *defunc* Gongola State is the present Taraba State. [*dɪfʌŋk*] instead of /**dɪfʌŋk**t/.

18. *Adjunc* means extra information. [*ædʒʌŋk*] instead of /**ædʒʌŋkt**/.

19. Always *respec* your elders. [*rɪspek*] instead of /**rɪspekt**/.

20. What is the *cos* of this handset? [*kɒs*] instead of /**kɒst**/.

21. The ship is approaching our *coas*. [*kəʊs*] instead of /**kəʊst**/.

22. Please *roas* this maize for me. [rəʊs] instead of /**rəʊst**/.

6.1 Analysis/Discussion

Considering the above data, it is clear that the consonant deleted in **1**-**6** involves the alveolar plosive /**t**/, which usually occurs when preceded by the alveolar nasal consonant /**n**/. From **7**-**10**, the consonant deleted still remains the alveolar plosive /**t**/ but this time around, the deletion occurs when it is preceded by the labiodental fricative /**f**/ or the alveolar lateral /**l**/. Then from **11**-**14**, we can see that the deleted consonant is the alveolar plosive /**d**/, and it usually occurs when preceded by the alveolar nasal consonant /**n**/ or the alveolar lateral /**l**/. Furthermore, from **15**-**22**, the consonant involved in the deletion there is, once again, the alveolar plosive /**t**/. However, as we can see clearly, the deletion often takes place when it is preceded by the velar plosive /**k**/, the velar nasal /**n**/ and the alveolar fricative /**s/**.

Furthermore, this phenomenon of consonant deletion by English-Platoid bilinguals as displayed in the above data, as a matter of fact, could affect the semantics, comprehension or intelligibility of the words concerned. This is because the words have been altered both orthographically and phonetically. Imagine an English-Platoid bilingual, who says to his interlocutor, who is a native speaker of English in a conversation, for instance: *Let us go and **plan** cassava*; *INEC is planning to **shif** the 2019 general elections*; *I had **lef** before you came*; *What is my **faul** in this matter*?; *The **shaf** of his car had been removed*; *Our meeting today will **hol** by 2:00 pm*; *Please **fol** the bed sheet gently*; *What is the **cos** of this handset*?; etc. This could get the interlocutor, who is a native speaker of English confused because the words contained in these sentences are obviously unfamiliar to him/her thereby impeding intelligibility or comprehension. As an implication then, for such a native speaker of English to get acquainted with consonant deletion by English-Platoid bilinguals, he or she needs to devote time to learn this phonological phenomenon.

6.2 The Phonetic Factor Responsible for this incidence

To be able to conclusively capture or pin down the phonetic factor that accounts for this phenomenon among the English-Platoid bilinguals, we present here a data (comprising mainly common nouns) elicited from ten Platoid indigenous languages as well as few of their consonant systems (few because some of the languages are yet to be written), which forms the second part of our data for this study. The words contained in the data in question are both tone-marked and transcribed phonetically for clarity on the part of the readership, as outlined below:

(B) 1. **Tarok Consonant Sounds & Some Lexical items**

Place→ Manner↓	**Labial**	**Labio-dental**	**Alveolar**	**Palato-alveola**	**Palatal**	**Velar**	**Labio-velar**	**Glottal**
Plosive	**p** **b**		**t** **d**			**k** **g**	**kp** **gb**	**ʔ**
Implosive	**ɓ**		**ɗ**					
Fricative		**f** **v**	**s** **z**	**ʃ** **ʒ**		**ɣ**		**h**
Affricate				**ʧ** **ʤ**				
Nasal	**m**		**n**		**ɲ**	**ŋ**		
Lateral			**l**					
Trill			**r**					
Semi-vowels					**y**		**w**	

Word		**Gloss**
(a) Nzhi	/ŋzī/	'house'
(b) Itọ̀k	/ɪtɔk/	'chair'
(c) Iyamrì	/ījɑmrì/	'food'
(d) Ǹding	/ŋ̀dɪŋ/	'water'
(e) Ìkpáng	/ìkpáŋ/	'plate'
(f) Ákwàp	/ákʷàp/	'shoe'.

1. Mwaghavul Consonant Sounds & Some Lexical items

Place→ Manner↓	Bilabial	Labio-dental	Alveolar	Palato-alveolar	Palatal	Velar	Glotal
Plosive	**p b**		**t d**			**k g**	**ʔ**
Implosive	**ɓ**		**ɗ**				
Fricative		**f v**	**s z**	**ʃ ʒ**		**ɣ**	**h**
Affricate				**ʧ ʤ**			
Lateral			**l**				
Trill			**r**				
Approximant	**w**				**Y**		
Nasal	**m**		**n**			**ŋ**	

Word		**Gloss**
(a) Làngtíng	/làŋtíŋ/ 'witness'	
(b) Shikbish	/ʃīkbīʃ/	'sin'
(c) Mpúlpùl	/mpúlpùl/	'butterfly'
(d) Ǹtìsh	/ŋ̀tìʃ/	'snail'
(e) Dàkwat	/dàkʷāt/	'male hunter'
(f) Naanfwang	/nāānfwāŋ/	'God guides'.

2. Ngas Consonant Sounds & Some Lexical items

Place→ Manner↓	Bilabial	Labio-dental	Alveolar	Palato-alveolar	Palatal	Velar	Glotal
Plosive	p b		t d			k g	?
Implosive	ɓ		ɗ				
Fricative		f v	s z	ʃ ʒ		x	h
Affricate			ts	ʧ ʤ			
Lateral			l				
Trill			r				
Approximant	w				y (j)		
Nasal	m		n			ŋ	

In addition to the individual consonant sounds, Ngas has:

(i) Palatalised consonants usually written as: p^y, b^y, k^y, g^y, m^y and f^y;

(ii) Labialised consonants written as: p^w, b^w, $ɓ^w$, k^w, m^w, n^w, g^w, f^w, s^w, $ʒ^w$, $ʧ^w$, $ʤ^w$ and;

(iii) Pre-nasalised consonants written as: ^{m} p, ^{m} b, ^{n}t, ^{n}d, ^{n}s and ^{n}ʒ.

Word		Gloss
(a) Chùk	/tʃòk/	'knife'
(b) Pùk	/pùk/	'soup'
(c) Nyár	/njɛ́r/	'bird'
(d) Ngón	/ngóŋ/	'snake'
(e) Gùrm	/gùrəm/	'person'
(f) Chọ̀k	/ʧɔ̀k/	'neck'.

3. Berom Consonant Sounds & Some Lexical items

Place→ Manner↓	Bilabial	Labio-dental	Alveolar	Palato-alveolar	Palatal	Velar	Glotal
Plosive	**p b**		**t d**			**k g**	
Fricative		**f v**	**s ts z**	**ʃ**			**h**
Affricate				**ʧ ʤ**			
Lateral			**l**				
Trill			**r**				
Approximant	**w**				**j**		
Nasal	**m**		**n**			**ŋ**	

Word		**Gloss**
(a) Ǹshí	/ŋ̀ʃí/	'water'
(b) Lóh/ló/		'house'
(c) Hwóng	/hwóŋ/	'girl'
(d) Ndém	/ndém/	'law enforcement agent'
(e) Vú	/vú/	'dog'
(f) Pyénrè	/pjénrè/	'food'.

4. Piapung Consonant Sounds & Some Lexical items

Place→ Manner↓	Bilabial	Labio-Dental	Alveolar	Palatal	Velar	Glottal
Plosive	**p b**	**t d**	**ʤ**		**k g**	
Implosive	**ɓ**	**ɗ**				
Fricative		**f v**	**s z**	**ʃ ʒ**		**h**
Nasal	**m**	**n**			**ŋ**	
Liquid		**l**		**r**		
Semi-vowel				**y**		**w**

Word		Goss
(a) Kyang	/kjáŋ/	'hoe'
(b) Ham	/hàm/	'water'
(c) Shim	/ʃím/	'yam
(d) Shẹrẹp	/ʃɛrɛp/	'fish'
(e) Kong	/kɔ̄ŋ/	'river'
(f) Tẹng	/tɛŋ/	'tree'.

6. Kulere

Word		Gloss
(a) Àm /àm/		'water'
(b) Riek	/rɪēk/	'eye'
(c) Rìyau	/rìjɑʊ/	'hand'
(d) Taná	/tæná/	'nose'
(e) Lush	/lūʃ/	'tongue'
(f) gɨrau	/gɨɑʊ/	'teeth'.

7. Iguta

Word		Gloss
(a) Mini	/mɪnɪ/	'water'
(b) Rizhì	/rɪzì/	'eye'
(c) Wərí	/wərí/	'hand'
(d) Bìmu	/bìmū/	'nose'
(e) Rəlem	/rəlēm/	'tongue
(f) Anyíyí		'teeth'.

8. Ron

Word **Gloss**

(a) Kámbọng /kámbɔŋ/ 'cocoyam'

(b) Challà /ʧəlà/ 'peace'

(c) Dán'máfwàshì /dánmáfwàʃi/ 'snake'

(d) Bakam /bākām/ 'knife'

(e) Rawúl /rɔwúl/ 'potatoes'

(f) Ligit /līgīt/ 'drinks'.

9. Afizere

Word		**Gloss**
(a) Ìshọsh	/ìʃɔʃ/	'bee'
(b) Ìnyám	/ìɲám/	'antelope'
(c) Àgàbú	/àgàbú/	'dog'
(d) Nànámàng	/nànámàŋ/	'girls'
(e) Ìzọs	/ìzɔs/	'fish'
(f) Kùrộng	/kùrɔ́ŋ/	'fire'.

10. Mupun

	Word		**Gloss**
(a)	Fwan	/fʷuan/	'rain'
(b)	Kam	/kam/	'stick'
(c)	Pel	/pɛl/	'leaves'
(d)	Wur	/wur/	'breast'
(e)	Fwat	/fʷuat/	'ashes'
(f)	Amkur	/amku:r/	'sea'.

As we carefully consider the data from the ten indigenous Platoid languages above, one thing that can be observed easily is the fact that their words do have a cluster of consonants at word-initial positions but do not at word-final positions. Even in Ngas language (number three) where we would have considered the word *Gùrm* 'person' as an exception, we discover that in actual realisation or articulation, a schwa vowel is inserted between the two consonants at the word-final position. In fact, the schwa is neither weak nor silent but sonorous to the extent that it receives a tone-mark according to its transcription: /gùrə̀m/.

In addition, it is not out of place to say that since consonant cluster exists word initially in Platoid languages, English-Platoid bilinguals do not delete consonants in English words with a cluster of consonants word initially. Evidence of this is clearly seen in our data presentation, and some of the words include: *nzhi* /ŋzī/ 'house', *ǹding* /ŋ̀dɪŋ/ 'water' (Tarok); *mpúlpùl* /mpúlpùl/ 'butterfly', *ǹtìsh* /ŋ̀tìʃ/ 'snail' (Mwaghavul); *ngón* /ngóŋ/ 'snake' (Ngas); ǹshí /ŋ̀ʃí/ 'water', *hwóng* /hwóŋ/ 'girl', *ndém* /ndém/ 'law enforcement agent', *pyénrè* /pjénrè/ 'food' (Berom); *kyang* /kjáŋ/ 'hoe' (Piapung); and *fwan* /fʷuan/ 'rain', *fwat* /fʷuat/ 'ashes' (Mupun).

Similarly, according to the data, Platoid languages also have consonant cluster word medially, as seen in words such as *iya**mr**ì* /ījɑmrì/ 'food' (Tarok); *là**ngt**íng* /làŋtíŋ/ 'witness', *shi**kb**ish* /ʃīkbīʃ/ 'sin', *mpú**lp**ùl* /mpúlpùl/ 'butterfly', *Naa**nfw**ang* /nāānfwāŋ/ 'God guides' (Mwaghavul); *pyé**nr**è* /pjénrè/ 'food' (Berom); *ká**mb**ọng* /kámbɔŋ/ 'cocoyam', *cha**ll**à* /ʧəlà/ 'peace', *dán'má**fw**àshì* /dánmáfwàʃì/ 'snake' (Ron); and *a**mk**ur* /amku:r/ 'sea' (Mupun). Consequent upon this, it is also not out of place to suggest that consonants in English words that are clustered word medially do not get deleted by English-Platoid bilinguals.

Furthermore, as viewed from the data, it is true as well that the orthographic -ng which gives birth to the phonetic velar nasal /ŋ/, which usually occurs word medially and finally in English also operates equally in Platoid languages, as in *ǹdi**ng*** /ŋ̀dɪŋ/ 'water', *ìkpá**ng*** /ìkpáŋ/ 'plate' (Tarok); *là**ng**tí**ng*** /làŋtíŋ/ 'witness' (here it appears both medially and finally), *Naanfwa**ng*** /nāānfwāŋ/ 'God guides' (Mwaghavul); *hwó**ng*** /hwóŋ/ 'girl' (Berom); *ko**ng*** /kɔ̄ŋ/ 'river' *tẹ**ng*** /tɛŋ/ 'tree'. *kámbọ**ng*** /kámbɔŋ/ 'cocoyam' (Ron); and *nànámà**ng*** /nànámàŋ/ 'girls', *kùrọ́**ng*** /kùrɔ́ŋ/ 'fire' (Afizere). Since the dental-nasal *n* and the velar-plosive *g* constitute a digraph, deleting it word finally is practically impossible. Consequently, English-Platoid bilinguals maintain and articulate the sound correctly in English words that contain it both at medial and final positions.

6.3 Research Findings

Considering the data presentation and analysis above, the following are the findings of this study: (i) English-Platoid bilinguals delete the last consonant in a cluster of consonants due to the fact that consonant cluster does not exist word finally in Platoid languages; (ii) the word *gùrm* 'person' in Ngas appears to be diametrically opposed to (i) above when viewed orthographically but when viewed phonetically – gùrm /gùrə̀m/, it is in tandem. This is because in actual realisation, a schwa vowel is inserted between the two consonants at word final position, and the schwa becomes sonorous to the extent of being tone-marked; (iii) Platoid languages have consonant cluster word initially as in *nzhi* /ŋzī/ 'house' (Tarok), *mpúlpùl* /mpúlpùl/ 'butterfly', (Mwaghavul), *ngón* /ngóŋ/ 'snake' (Ngas), *ndém* /ndém/ 'law enforcement agent' (Berom), *kyang* /kjáŋ/ 'hoe' (Piapung), etc. and as such, English-Platoid bilinguals do not delete any consonant in English words containing a consonant cluster word initially; (iv) Platoid languages also have consonant cluster word medially as observed in these words - *iya**mr**ì* /ījɑmrì/ 'food' (Tarok), *Naa**nfw**ang* /nāānfwāŋ/ 'God guides' (Mwaghavul), *pyé**nr**è* /pjénrè/ 'food' (Berom), *ká**mb**ọng* /kámbɔŋ/ 'cocoyam' (Ron), *a**mk**ur* /amku:r/ 'sea' (Mupun), etc. and for this reason, consonant deletion by English-Platoid bilinguals does not take place in English words having a cluster of consonants at the medial position; (v) the orthographic -ng which gives birth to the phonetic velar nasal /ŋ/, and which usually occurs word medially and finally in English is a very common occurrence in many words of Platoid languages such as *nànámà**ng*** /nànámàŋ/ 'girls', *kùrọ́**ng*** /kùrɔ́ŋ/ 'fire' (Afizere); *hwó**ng*** /hwóŋ/ 'girl' (Berom); *là**ng**tí**ng*** /làŋtíŋ/ 'witness', *Naanfwa**ng*** /nāānfwāŋ/ 'God guides' (Mwaghavul); ***kong*** /kɔ̄ŋ/ 'river' ***tẹng*** /tɛŋ/ 'tree', ***kámbọng*** /kámbɔŋ/ 'cocoyam' (Ron); ***ǹding*** /ŋ̀dɪŋ/ 'water', ***ìkpáng*** /ìkpáŋ/ 'plate' (Tarok); etc. – making it difficult for English-Platoid bilinguals to delete either the dental-nasal *n* or the velar plosive *g* in English words that contain them both at the medial and final positions because they form a digraph.

7 Contribution to Knowledge

Certainly, this research has contributed in no small measure to knowledge as far as the field of Language & Linguistics is concerned. Generally, making this kind of research available in language study as an addition to the existing body of knowledge in which it serves as a reference material for laymen, language enthusiasts as well as students and scholars in general linguistics globally is actually a good contribution. Specifically, our presentation of data and analysis of both data (A & B) have exposed to the readership the reason why English-Platoid bilinguals delete the last consonant in a cluster of consonants, and that is, no consonant cluster word finally in Platoid languages. Furthermore, the insertion of a schwa in the Ngas word *gùrm* /gùrəm/ 'person' has given credibility to this claim. Consequently, the effect or influence of this is brought to bear on the English-Platoid bilinguals' use of the English language, which is popularly referred to as mother-tongue interference under teaching and learning situation. Besides, this study seems to be a pioneer, and as such, it is definitely expected to produce chain reactions because it will surely provoke more researches in this area of linguistic study, not just in Nigeria and Africa alone but also the rest of the world.

8 Conclusion

This paper, in its best attempt has examined consonant deletion in the speech of English-Platoid bilinguals. From the data gathered, presented and analysed, it revealed that Platoid languages do have evidence of consonant cluster at word-initial and medial positions but do not at word final position. Therefore, we validly conclude that English-Platoid bilinguals do delete consonants at word final position in English words containing them (consonants) due to the fact that consonant cluster does not exist word finally in Platoid languages. As a result, English-Platoid bilinguals have transferred this phenomenon into the English language, a situation which is regarded as mother-tongue interference in language teaching and learning. Also, it is worthy of mention to point out here that where a cluster of consonant appears to be present orthographically, it only exists as a digraph, as in *ìshọ**sh*** 'honey bee', *nànámà**ng*** 'girls' (Afizere); *hwó**ng*** /hwóŋ/ 'girl' (Berom); *là**ng**tí**ng*** /làŋtíŋ/ 'witness', *Naanfwa**ng*** /nāānfwāŋ/ 'God guides' (Mwaghavul); *ko**ng*** /kɔ̄ŋ/ 'river' *tẹ**ng*** /tɛŋ/ 'tree', *kámbọ**ng*** /kámbɔŋ/ 'cocoyam' (Ron); *ǹdi**ng*** /ŋ̀dɪŋ/ 'water', *ìkpá**ng*** /ìkpáŋ/ 'plate' (Tarok); etc.

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