A Survey on the Imaging Systems, Pattern Recognition and Classification Techniques used in the Detection of Oral Cancer

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Abstract—Oral cancer is a vital global healthcare problem. An estimated 128,000 deaths and 263,900 new cases from oral cavity cancer occurred in 2008 worldwide. The World Health Organization considers oral cancer as a major health challenge in India. For oral cancer five-year survival rate is 52% and this number has not altered in the last 25 years. The major reason for such a poor survival rate is its late diagnoses. However, when cancer is diagnosed early, the five-year survival rate increases to around 80%. Several technologies have emerged as an adjunct in diagnosing the oral cavity for the malignant lesions. This paper emphasizes on these available aids to detect and classify the oral cancer/precancerous tumors.

Index Terms—Squamous Cell Carcinoma, Image Processing, Classification, Malignant lesions.

I. INTRODUCTION

Oral cancer can be defined as an abnormal and uncontrolled cell division in the oral cavity which includes the lips, palate, tongue, inner cheeks and gums. A tumor (neoplasm) can be either malignant or benign. Lesions which can turn into malignance are usually either a red patch (erythroplakia) or white patch (leukoplakia) (Fig. 1 and Fig. 2). Currently, 90–95% of all new instances of oral cancer are Squamous Cell Carcinomas (SCC) which originates from lining mucosa [2] shown in Fig. 3. Even though the exact cause for Squamous Cell Carcinomas is still undefined, smoking or chewing of tobacco are commonly associated with oral cancer. Malignant lesions are usually pain-free in their initial stage and are usually not noticed by the patient, therefore late diagnosis of this disease is a common feature. In this paper, we refer oral cancer as any malignant neoplasm which is included in ICD-10 codes: C00 – C06 [4]. The symptoms for an oral cancer at an earlier stage [3] are: 1) White, red or mixture of white and red patches inside the mouth or on lips 2) Bleeding in the mouth 3) Any sore or discolored area in the mouth which does heal for more than 14 days 4) A chunk in the neck 5) Difficulty or pain when swallowing. These symptoms identify the suspect for a cancer. The doctor who suspects the malignant tumor in a patient can go ahead in one of the following ways, 1. X-rays study to find the cancer’s precise location; 2. Carry out brush biopsy; 3. Scalpel out a portion of the lesion for biopsy; 4. Perform the surgery; 5. Explore the surrounding tissues to determine if the cancer has spread to the lymph node. The ultimate goal is to reduce mortality and morbidity and to improve patients’

DOI: 03.AETS.2014.5.349
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quality of life. Significant research has been carried out in the past two decades to aid the dentists in detecting oral cancerous lesions. Our extensive literature review has focused on the area of medical imaging techniques Image processing, Pattern Recognition and Classification methods to detect and classify the oral cancer. The remainder of this article is organized as follows. Section 2 presents a survey of imaging techniques which help in detecting the malignant lesions. Section 3 focuses on the application of Image processing, pattern recognition and classification algorithms used as adjunct in malignant lesions detection and classification. Finally, Section 4 draws some conclusions and identifies directions for future research.

![Images of Erythroplakia, Leukoplakia, and Squamous Cell Carcinomas](image1.png)

**Figure 1:** Erythroplakia, Figure 2: Leukoplakia, Figure 3: Squamous Cell Carcinomas

**II. SURVEY OF IMAGING TECHNIQUES USED IN DETECTION OF THE MALIGNANT LESIONS**

As clinical examination gives direct visualization, it cannot evaluate depth of lesion. Cross-sectional imaging has become an essential tool in the pretreatment evaluation of these cancers. The characteristics of a good diagnosing system are 1. High Sensitivity (Low false negatives), 2. High Specificity (Low false positives), 3. Should be cost effective, 4. Should be safe and acceptable to the patient, 4. Should be able to detect the tumor in its earliest stage. Figure 4 depicts the interrelationship of all these requirements. Cancer tumor can be imaged by a number of biomedical imaging techniques. X-ray, Computed Tomography (CT), Magnetic resonance imaging (MRI), Ultra Sound (US) imaging, and fluorine 18 fluorodeoxyglucose (FDG) positron emission tomography (PET), fusion PET and CT (PET-CT) are the currently used imaging techniques to get the depth and the area of the malignant tumor which can help in deciding the appropriate treatment. Below are some research papers reviewed in which the sensitivity and specificity evaluation were done on the available medical imaging systems.

Ref. [9] compares ultrasound, PET using 18F-FDG, CT and MRI of head and neck with the postoperative histological tissue evaluation. Compared with the histological findings, the diagnostic techniques gave the following results: Ultrasound: sensitivity 84%, specificity 68%, accuracy 76%; PET: 70%, 82%, 75%; MRI: 64%, 69%, 66%; CT: 66%, 74%, 70%. This indicates PET has the highest specificity while ultrasound has the highest sensitivity when compared with the other staging procedures.

Ref. [7] compares PET/CT and US, and also the combined use of both for the detection of a subclinical regional recurrence in patients after HNSCC treatment. For PET/CT sensitivity is 86% and specificity is 82%; for US values are 81% and 87%, respectively.

Ref. [6] deals with the detection of primary tumors and cervical nodal spreading of SCC using CT/MRI, 18F-FDG PET of the oral cavity and the results were compared with histological evaluation. The sensitivity of CT/MRI for the identification of nodal metastases was 52.6% and that of 18F-FDG PET 74.7%, the specificity of CT/MRI 94.5% and that of 18F-FDG PET 93.0%.

Ref. [1] investigated the detection of cervical lymph node spreading of head and neck cancer by FDG-PET, CT, MRI, sonographic and the results were compared with histopathological findings. FDG-PET reached the specificity of 94% and a sensitivity of 90%. CT with a sensitivity of 82% (specificity 85%) and of MRI sensitivity of 80% (specificity 79%). Sonography revealed a sensitivity of 72%.

Table I summarizes the results of existing biomedical imaging for diagnosing the tumor in the oral cavity. The values are of sensitivity and specificity when compared with the histopathological findings which is considered as the Gold standard. Highest average Sensitivity is seen in fusion of PET and CT imaging where as highest average Specificity is in fusion of MRI and CT imaging.

**III. IMAGE PROCESSING, PATTERN RECOGNITION AND CLASSIFICATION ALGORITHMS USED AS ADJUNCT IN MALIGNANT LESIONS DETECTION AND CLASSIFICATION**

Using only color information, Ref. [5] investigated the effective image analysis methods for the separation of two oral neoplasm, oral lichenoid reactions and oral leukoplakia. For color analysis of mucosal images Hue-Intensity-Saturation (HIS), Red-Green-Blue (RGB), Infrared-Red-Green (Irg), La*b* and I1I2I3 color representations were used. Evaluation of classification performance was done with the help of Gaussian
quadratic, Fisher’s linear discriminant, Multilayer Perceptron and k-Nearest Neighbor classifiers (kNN).

Mean color differences between abnormal and normal regions are the elements in the feature vector.

**TABLE I: EVALUATION OF VARIOUS IMAGING TECHNIQUES**

<table>
<thead>
<tr>
<th></th>
<th>CT</th>
<th>MRI</th>
<th>MR/CT</th>
<th>PET/CT</th>
<th>18F-FDG PET</th>
<th>Ultra Sound</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sen</td>
<td>66</td>
<td>74</td>
<td>69</td>
<td>-</td>
<td>-</td>
<td>70</td>
<td>82</td>
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<tr>
<td>Spl</td>
<td>86</td>
<td>82</td>
<td>-</td>
<td>-</td>
<td>81</td>
<td>74.7</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>82</td>
<td>85</td>
<td>80</td>
<td>79</td>
<td>90</td>
<td>89</td>
<td>82.5</td>
</tr>
<tr>
<td>74</td>
<td>80</td>
<td>72</td>
<td>74</td>
<td>52.6</td>
<td>86</td>
<td>82</td>
<td>78.3</td>
</tr>
</tbody>
</table>

HSI color system was chosen as the best depending on the results obtained. Using only the color information 70.0% of leukoplakia and 94.6% lichenoid reactions were correctly classified.

Ref. [8] proposed a novel method for noticing and grading oral precancer. The wavelet coefficients of transmission electron microscopy images were used in selection of the feature vector, this vector was then used to train the Artificial Neural Network (ANN). Results of classification were 71.43% to 95.73%.

Ref. [11] aimed at the spectroscopic studies of Pulsed laser-induced autofluorescence at 325 nm excitation on the malignant as well as benign lesions. The spectral analysis and classification were carried out using principal component analysis (PCA) and ANN. In case of PCA, spectral residuals were used and in ANN, parameters like mean, standard deviation, total energy and spectral residual were used. In the case of ANN specificity and sensitivity are 100 and 96.5% for the data set considered and for PCA, specificity and sensitivity are 100 and 92.9%, respectively.

Ref. [12] proposed a new method of feature selection using Recursive Feature Elimination (RFE) and mean-shift techniques to increase separation power of the feature vectors. Evaluation of the proposed work is done on in-vivo recorded Laser Induced Fluorescence (LIF) data set. In the first step, using discrete wavelet transform features are extracted from LIF spectra and then the most relevant features are selected from all the features using the proposed feature selection technique. Finally, separation is done using Support Vector Machine (SVM). Specificity of above 99% and Sensitivity of above 95% are obtained using the proposed method.

Ref. [14] proposes a new method to mark the boundary of neoplastic oral mucosa using autofluorescence imaging. Using a Multispectral Digital Microscope (MDM), autofluorescence and white light images were obtained at an excitation of 380 nm, 450 nm, 365 nm, and 405 nm. The best bifurcation between tumor and normal areas was obtained at 405 nm excitation. Results were 100% sensitivity and 91.4% specificity.

Using macroscopic “wide-field” imaging and microscopic “high-resolution” imaging Ref. [15] proposes a low cost device for detecting the malignant tumour. The classification algorithm, with the single input feature of red to green fluorescence ratio, based on linear discriminant analysis, demonstrated 91.4% specificity and 100% sensitivity for distinguishing normal from tumor.

Ref. [13] discusses the classification of the histopathological h&e stained biopsy images. For taking decision as to whether the biopsy sample is malignant or benign, ANN data set includes the intensity and texture (Haralick) features extracted from the images. Detection efficiency was up to 90%.
Ref. [10] proposes a system to segment oral cancers. The Marker Controlled Watershed segmentation tumor is used for detection of the neoplasm. Gray Level Co-occurrence Matrix is used in extraction of features like Contrast, Entropy Energy, Correlation, and Homogeneity. SVM classifier uses the extracted features to classify the tumor as benign or malignant. It also discusses the various feature extraction and classification methods used in the detection of oral cancer.

Table II gives the review of the research papers in which the Image processing techniques, pattern recognition and classification algorithms were applied to the images taken from the medical imaging systems like X-ray, CT, MRI, Ultrasound and PET.

IV. CONCLUSION

In this article, we have analyzed the efficiency various medical imaging systems with respect to the detection of cancerous/ precancerous tumors. We have found out that highest average sensitivity is seen in fusion of PET and CT imaging where as highest average specificity is in fusion of MRI and CT imaging. Applications of various image processing techniques, pattern recognition and classification algorithms to detect and classify cancers are being reviewed. Macroscopic “wide-field” imaging and Microscopic “high-resolution” imaging with linear discriminant analysis gives a high specificity and sensitivity. Given the high mortality and morbidity rates associated with oral cancer, there is a demand for a screening programme, either as a population based measure, targeted, or opportunistic.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Method Used</th>
<th>Result</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrimination of oral lichenoid reactions and oral leukoplakia</td>
<td>La<em>b</em> HSI, I1I2I3, Irg and RGB for color analysis, Gaussian quadratic, Fisher’s linear discriminant, Multilayer Perceptron and kNN-Nearest Neighbor classifiers</td>
<td>70.0% of leukoplakia and 94.6% lichenoid reactions were correctly classified.</td>
<td>[5]</td>
</tr>
<tr>
<td>Detecting and staging oral precancer</td>
<td>Artificial Neural Network on microscopic images</td>
<td>71.43% to 95.73%.</td>
<td>[8]</td>
</tr>
<tr>
<td>Increase discrimination ability of the feature vectors</td>
<td>Recursive Feature Elimination, optical spectroscopy based on Laser Induced Fluorescence</td>
<td>Sensitivity: Above 95% and specificity: Above 99%</td>
<td>[12]</td>
</tr>
<tr>
<td>Detecting the cancerous tumour</td>
<td>Macroscopic “wide-field” imaging and Microscopic “high-resolution” imaging with linear discriminant analysis</td>
<td>100% sensitivity and 91.4% specificity</td>
<td>[15]</td>
</tr>
<tr>
<td>Classification of Histopathological “h &amp; e” stained biopsy images</td>
<td>ANN on biopsy images</td>
<td>90%</td>
<td>[13]</td>
</tr>
<tr>
<td>Segment and classifies oral cancers at an earlier stage</td>
<td>Marker Controlled Watershed segmentation, Gray Level Co occurrence Matrix (GLCM) and Support Vector Machine (SVM) Classifier</td>
<td>92.5%</td>
<td>[10]</td>
</tr>
</tbody>
</table>

Many Oropharyngeal squamous cell carcinomas (OSCCs) are preceded by a potentially malignant disorder (PMD) which may be noticed by the patient or detected by a professional. Early detection, diagnosis and treatment of oral cancer have been shown to significantly increase the survival rate of those with the disease. The ultimate goal is to reduce mortality and morbidity, and to improve patients’ quality of life. Currently as discussed above there are many imaging systems like CT, MRI, Thermal imaging and Ultrasonography. The drawback of these imaging systems is that they are not portable. There is need for an imaging system which is portable so that it can be taken to the villages for the scanning purpose.

REFERENCES


