Machine learning based Computer Aided Tongue Diagnosis system for illness Prognosis

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ABSTRACT
Examining a patient's pulse, eyes, face, tongue, etc. has been a standard practice in medicine since ancient times. Because the tongue contains so much information, observing it is a hard task. The medical professional may learn something new by studying the Tongue's many regions, colours, and coatings. To diagnose internal organ problems by studying the tongue calls for a great deal of training and expertise. Disease prediction using tongue image analysis (DPTIA) was the central emphasis of the suggested model's artificial intelligence architecture. As a first step, the test picture undergoes pre-processing, various noise reduction processes, and colour improvements via the use of Fast Non-Local Mean (FNLM) filtering. To do this, the picture resolutions in the dataset are pre-processed. To further extract textural information, the Grey Level Cooccurrence Matrix (GLCM) is also used. The last step is to utilise the retrieved characteristics to identify the various illnesses using a Hybrid Extreme Learning Machine (HELM) classifier. A variety of diseases, including appendicitis, bronchitis, gastritis, heart disease, and pancreatitis, may be predicted using the DPTIA model. The proposed Computer Aided Tongue Diagnosis System (CATDS) model outperforms state-of-the-art methods like Random Forest and Support Vector Machine (SVM).

1. Introduction

A better quality of life for the community is one goal of health informatics, a relatively new discipline. The field of health informatics encompasses both the medical and computer engineering subfields. Finding and developing new ways to gather, comprehend, analyse, and research human data is aided by this. The data originates from a variety of sources and is collected in accordance with data privacy regulations. In order to aid the community in illness prediction, cure, and monitoring, this data is further processed utilising engineering or computational methodologies. Health informatics, in its most basic form, is a branch of medicine that uses computational methods to supplement the work of medical professionals so that they may better care for their communities. From data collection and storage to data organisation and security, computer science is an integral part of health informatics. At any time, computational methods may be used to extract the stored data for analysis. The analytical capability of data is enhanced by computer science, which aids medical practitioners in quickly identifying diseases or predicting future difficulties of patients.

Consequently, it enhances the speed of issue solving and turnaround time. Doctors have been checking patients' vitals (heart rate, blood pressure, eye movement, facial expression, tongue, etc.) since ancient times. Simply placing fingers on the arterial pulse and calculating the pulse rate constitutes a pulse examination. As part of a comprehensive eye exam, a doctor will look at the patient's eye colour, eyelid health, and blood vessels. More careful evaluation of different areas on the tongue is needed during a tongue examination in order to detect primary level pathology. Humans rely on their tongues for a variety of vital functions, including digestion, taste perception, and speech. In human existence, it is crucial. This thesis seeks to further investigate and analyse techniques of tongue diagnostics for the prediction of different illnesses. One non-invasive way to assess a patient's internal organ condition in oriental medicine systems like Traditional Chinese Medicine (TCM), Indian Ayurvedic Medicine (IAM), Traditional Korean Medicine (TKM), and Japanese Traditional

Herbal Medicine is through tongue diagnosis [1]. A visual study of the tongue's colour, substance, coating, shape, and mobility provides the basis for the expert's assessment, which in turn informs the diagnostic method. When it comes to disorders that impact the tongue or irregularities in its appearance, traditional tongue diagnostics has a better chance of detecting the issue. As an example, cold syndrome may be indicated by a white, greasy coating on the tongue, whereas heat syndrome might be indicated by a thick, yellow coating. Infection, inflammation, stress, immunological disorders, and endocrine abnormalities are all associated with each of these syndromes.

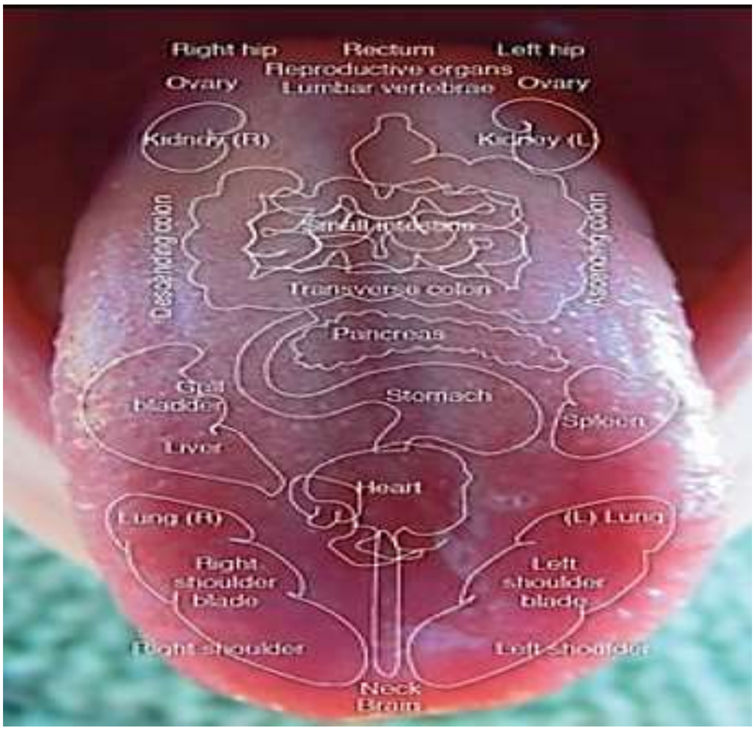

Figure 1.Reflexes of Tongue

(Source: https://balancingtouchreflexology.wordpress.com/2014/08/26/tongue-reflexology/)

As seen in Figure 1, the various portions of the tongue and the associated internal organs are shown according to IAM. The tip of the tongue reflects pathological alterations in the lungs and heart, whereas the sides of the tongue reveal abnormalities in the gallbladder and liver. Whereas the centre of the tongue reflects pathological changes in the stomach and spleen, the root of the tongue reflects pathological abnormalities in the kidneys, intestines, and bladder region..

However, different clinicians are likely to get to different diagnostic findings for the same patient when it comes to traditional tongue diagnosis. This is because the level of clinical knowledge of the clinician is significantly reliant on the process. Thanks to the use of computers and other field-relevant methodologies, computer-aided methods for tongue diagnosis may thankfully improve upon these limitations [2]. Thanks to advancements in computer science and technology, modern tongue diagnostics now include objective, quantitative, and automated auxiliary studies, which aid medical practitioners in establishing more precise illness diagnoses.

Tongue Image Analysis For Healthcare Applications

Tongue diagnosis is a diagnostic approach used in Chinese medicine and plays a significant part in assessing numerous disorders. Simple, immediate, less expensive, and non-invasive remedies to many medical conditions may be revealed via visual examination of the human tongue. Traditional Western medicine views the tongue as a diagnostic instrument that may reveal early signs of illness [3]. Tasting anomalies may indicate a number of illnesses and conditions; for instance, a change in tongue colour can signal Parkinson's disease, vitamin deficiency, AIDS, Melkersson-Rosenthal disease, Down syndrome, diabetes, and a host of others. On top of that, IAM has been a widely used diagnostic technique for decades, therefore it must be valid. In order to extract crucial pathogenic facts from human bodies, IAM doctors have looked at images of the tongue, which include the colour, texture, and geometrical structure of the tongue.

Figure 2 depicts three typical tongue textures: red point, crack, and fissure. It is common to see a red spot on the surface of the tongue, which indicates appendicitis, and those with atypical tongue crack characteristics are in an abnormal condition. In addition, several diseases are thought to be indicated by the form of the tongue. Various tongue forms may be used to describe internal organ pathology in a generic sense [4]. The colour of the tongue is one of the most important indicators of a person's health when compared to other characteristics. The clinical information included in the patient's tongue colour is an additional essential metric in illness evaluation. In IAM, physicians use tongue analysis as a diagnostic tool because they believe that diseased changes to internal organs might influence the colour of the tongue's body. There are two main categories into which tongue colour is often categorised: substance colour and coating colour. The primary component is often the tongue substance, with the coating being created using materials that float on top of it[5][6][7].White, grey, black, or yellow make up the majority of tongue coating colours, however reddish shades of red, bright red, deep red, and purple are also possible[8][9]. The two tongue hues stand out from each other.

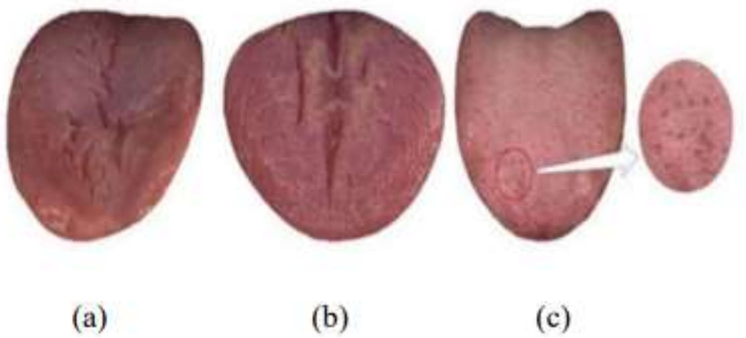

Figure 2 Sample Tongue Images with Distinct Textures (a) Tongue Fissure (b) Tongue Crack, (c) Image with a Local Substance

Tongue Diagnosis Using Computer-Aided Detection

As a well-known paradigm in clinical medicine and biology, tongue analysis has emerged in recent decades as a preeminent issue in early illness prediction. As a result, there are inherent limitations that conceal the clinical domains and traditional tongue examination is inevitable[10]. Firstly, it is not feasible to calculate pictures of the tongue for purposes such as digital data storage, computer-based image prediction, or transmitting data over the Internet for telemedicine since the tongue is best examined visually with the naked eye rather than preserved by quantitative digital instruments. Second, a physician's expertise in medicine plays a role in the subjective selection process of tongue analysis. Authors have made many efforts to address the aforementioned problems by creating a systematic tongue diagnostic model, a framework for objective and quantitative tongue analysis.[11]. We provide a method for systematically inspecting the tongue for illness using digital picture and pattern analysis, which allows us to avoid mistakes and failures. The time and accuracy issues associated with traditional approaches like laboratory testing and eye exams are only two of its many drawbacks. Therefore, Deep Learning (DL) models based on Computer Aided Detection (CAD) are widely employed to attain better performance. They have tackled and overcome the problems associated with conventional classification techniques to a large degree. Tongue image capture, pre-processing, segmentation, feature extraction, feature selection, and classification are the several processes that make up the tongue diagnostic technique [12].

In order to calculate systematic tongue image analysis, it is necessary to acquire images of the tongue. In the last few decades, digital cameras have been employed for identifying tongue problems as part of digital imaging model implementation. Tongue image acquisition modules may be classified into two main types: hyperspectral imaging systems and colour imaging systems. The imaging method and lighting both have a role in classifying objects. The developers' belief is that meaningful information may be acquired for identification and classification procedures by recording pictures by illumination with a sequence of successive wavelengths [13].

Because intrusive procedures are expensive and not widely available, non-invasive alternatives are gaining popularity. To use these techniques, an expensive piece of equipment known as a Tongue Diagnosis System (TDS) is required for the capture of images of the tongue. The availability of examiners in distant areas is limited since such TDS requires trained operators [14]. In order to enhance the picture quality and colour correction procedure, these systems are equipped with various image capture sensors, light sources, and algorithms. The most important part of accurate tongue image analysis is getting good images of the tongue. Magnetic resonance imaging (MRI), velscopes, hyperspectral imaging (HSI), fluorescent imaging, and other specialised technology is available for use in acquiring images of the tongue. The quality of the acquired tongue picture is a fundamental concern in tongue image analysis. Because a medical professional's examination of a tongue picture is heavily dependent on the image's quality [15]. Because of factors such as tongue movement, coating, available light, etc., these photos are very noise-prone. The use of feedback gridlines to achieve form and colour repeatability has been investigated, and techniques for correcting colours to eliminate noise have also been suggested. Efforts are being made to develop a lightweight, inexpensive device that may be readily transported to outlying areas for the purpose of digital tongue image capture study and analysis. Research comparing computerised image analysis to that of human examiners has also shown promising outcomes [16].

Image Preprocessing: Feature extraction benefits greatly from this method. First, a colour adjustment is applied to the obtained tongue picture as a computer-free colour space; this is to alter the colour produced by the system units. The second stage is the systematic analysis of the tongue analysis model. Another option is to use image segmentation to remove the tongue from the original picture while keeping the face, lips, and mouth intact. The colour details that are created in colour photos captured by digital cameras rely on the imaging characteristics of the camera, since they undergo device-based colour space translation [17]. In addition, the variations in lighting are the root cause of the noise in colour photographs. Therefore, colour correction is a precondition for computing image examination and is necessary for precise picture capture in order to produce high-quality colour images. Adjusting the input and output intensities is a typical preprocessing step for operations performed with pictures at the most fundamental level of abstraction [17]. The pixel level describes this degree of abstraction. Improving certain picture attributes that are crucial for further processing or removing undesirable distortions are the main goals of preprocessing. Augmentation, normalisation, standardisation, scaling, denoising, and other sorts of image processing procedures are available. A matrix of image function values, often called brightness values, is a common way to express an image's intensity. In addition, pre-processing approaches include picture geometric modifications such scaling, translation, and rotation [18].

Image SegmentationImage segmentation is the technique of dividing a digital picture into several sections using groupings of pixels, often called superpixels, [18]. Image segmentation methods include pixel-based, edge-based, region-based, and more approaches. Histogram thresholding is used in pixel-based segmentation. Edge based segmentation makes use of genetic algorithms, fuzzy logic, neural networks, and edge operators. Different segmentation techniques are used, such as region-based segmentation (also known as region-growing), clustering, split and merge, and so forth. Reducing a picture's complexity or changing its representation into something simpler, more clear, and easier to analyse is the main objective of image segmentation. There are a couple alternative approaches that may work here. The bulk of the time, it's utilised to pinpoint certain visual features like objects and borders (lines, curves, etc.). A more detailed explanation would be that image segmentation involves assigning a label to each pixel in a picture in a manner that pixels sharing the same label have certain properties. There are a lot of various methods to segment images. Labelled pixels are similar to one another in certain ways. Extracting features: An image feature is a piece of information that is linked to an item or piece of material that helps to differentiate it from other items or content that are identical to it [19]. In order to describe the object, its attributes are utilised in conjunction with its class name. The main purpose of feature extraction in tongue disease diagnosis is to automatically learn the characteristics. It is common practice to use the shape, texture, and colour of a picture of the tongue to make a diagnosis of tongue illness. It is necessary to use the correct technique for feature extraction based on these features [20]. Selecting the appropriate extraction technique and determining which attribute out of many is a challenging task. Choosing features: A substantial role for bio-optimization techniques in feature selection has been shown by recent studies. The use of these methods in real-world AI applications led to enhanced performance, and they also serve as a foundation for deep learning models [21–22]. In addition, natural-inspired approaches perform better than Supervised and Unsupervised feature selection methods. Classification: Identification of tongue diseases is the first step in the classification procedure. In recent times, the use of Deep Learning algorithms has become popular widespread to use for classification tasks[23]. The network that was presented consists of different convolutional layers.

Segmenting the tongue, extracting characteristics of the tongue, and analysing the condition are the three elements that make up the modernised IAM tongue diagnostic method. By applying a segmentation algorithm to the original tongue picture, a more precise image of the tongue may be obtained. Since digitally captured pictures of the tongue include not just the tongue area but also portions of non-tongue regions (such as the lips, teeth, and so on), it is necessary to extract features from the whole image in order to characterise the tongue. The digitally acquired image of the tongue includes both the tongue and parts of the surrounding area that do not really belong to the tongue. But, interference from moving light and busy backdrops makes tongue image analysis a difficult procedure. This allows for the extraction of the tongue features essential to an IAM diagnosis. The characteristics are classified for illness diagnosis once they have been obtained. Tongue image feature extraction methods have been the focus of a lot of study recently. You may classify the methods of computer-assisted tongue diagnosis into two main groups, namely, single feature and multifeatured, based on the results of these studies. A great deal of work has gone into developing and implementing methods for tongue image analysis that rely on extracting a single feature. Even a simple description, such an object's colour, texture, shape, or orientation, might provide useful information to these algorithms. The process known as tongue image-based illnesses categorisation involves determining the kind of tongue picture that might potentially aid IAM physicians in making a more thorough diagnosis determination. In the past, many methods have been considered for illness categorisation using tongue images.

When clustered, some of these algorithms are very sensitive to changes in background illumination, some of them mistake the tongue for the lips, and yet others need further preprocessing, which complicates the classification process overall. Nonetheless, conventional image processing approaches form the basis of most of these systems. More recently, methods based on deep learning have been considered for automated tongue picture analysis. The performance of such deep learning algorithms is better than that of the most traditional methods for tongue segmentation, although those methods still have substantial limitations. The total difficulty of the classification process is increased by the extra preprocessing that is required, such as image enhancement. Similarly, brightness discrimination as a preprocessing step reduces a deep learning model's generalisability. But mask finds it; it just can't tell the difference between the various kinds of items. Since unrelated items were handled needlessly, the categorisation process is slow and inaccurate compared to what it might be. Systematic approaches for diagnosing the tongue, such as those for image segmentation and texture feature extraction, relied heavily on pattern classification models and image processing in previous decades. The field of image processing and pattern recognition has produced the most published papers. However, the key issues that have been hindered by this system type are still present and have not been rectified [26]. Although a technique for extracting features and classifying images of the tongue was first developed, subsequent work has focused on acquiring images of the tongue based on computerised analysis, with little to no improvement. Consequently, the recently created models have produced illogical, inconsistent, and generally useless outcomes. Unresolved and integrative issues include capturing colour details with maximum quality, balancing noise and difference induced by imaging module, characteristics of tongue colours, and extracting efficient features of tongue colours for diagnostic purposes. Different tongues have different colour, shape, coating, and texture features, which causes certain machine learning models to have poor classification performance. On the other hand, photographs of the tongue captured digitally often include non-tongue features like lips and teeth alongside the tongue itself. Applying an initial picture segmentation approach before feeding data into classification models will ensure an accurate tongue image.

Tongue Diagnosis Using Hybrid Extreme Learning Machine

In order to determine the state of the patient's internal organs, a noninvasive and very successful method is to examine their tongue. Traditional Korean Medicine, Traditional Japanese Herbal Medicine, and Integrative Acupuncture all use it to gauge a patient's health, therefore it must be doing something well. Actually, the attending physician's suggestions are crucial for the diagnosis; they will look at the tongue's colour, texture, coating, and movement, among other things. Extensive use of tongue diagnosis may be greatly expanded globally, especially in Western medicine, if it were no longer dependent on subjective and expert knowledge judgement. Thankfully, AI systems that use image processing algorithms as described in the literature have shown significant improvement in performance. While there are several methods for evaluating tongue photos, the construction of an automated machine learning model is still required for the diagnosis of illnesses connected to the tongue using this method. Because of this, developing a reliable model for evaluating tongue pictures in order to identify and categorise disorders using AI-based models is the main focus of this research effort. Traditional approaches rely on colour analysis of tongue features by clinicians. Unfortunately, diagnostic findings are often accompanied with ambiguity and subjectivity. When compared to other clinical tests, tongue colour analysis—a new way for illness analysis—reduces patients' physical defects. One of its main examinations is the classification of tongue pictures, according to IAM.

The structure, colour, and form of the tongue have been used by Chinese physicians to predict a patient's health status in recent decades. In ancient China, this was a common custom. The advancement of pattern recognition models and digital clinical imaging techniques is also considered significant in IAM. This is because, when used to medical analysis, computer-assisted tongue analysis yields data that is more precise, trustworthy, and impartial. Thus, the main emphasis of this chapter is on the use of Disease Prediction using Tongue Image Analysis (DPTIA). DPTIA is employed to categorise several diseases using the HELM classifier, including Healthy, Appendicitis, Bronchitis, Gastritis, Heart disease, and Pancreatitis. First, the sounds in the tongue photos are removed using FNLM, which also enhances the colours. Colour moments and the GLCM descriptor are also used to extract joint texture and colour information from the preprocessed picture. Lastly, the illnesses are classified using the retrieved characteristics using HELM. The suggested DPTIA performed better than the state-of-the-art approaches, according to the simulation findings. You can see the basic architecture for illness identification and categorisation from photos of the tongue in Figure 3. A preprocessing procedure is performed first to enhance picture quality and standardise the dataset. The next steps include segmentation, HFE, and HFS, which are carried out using deep learning models and image processing methods. In addition, optimisation methodologies are used in HFS methods to ascertain the correlations between a plethora of clinical characteristics [12]. The best features are also selected by these methods. In order to classify the various illnesses, the classification operation is carried out using deep learning and transfer learning models.

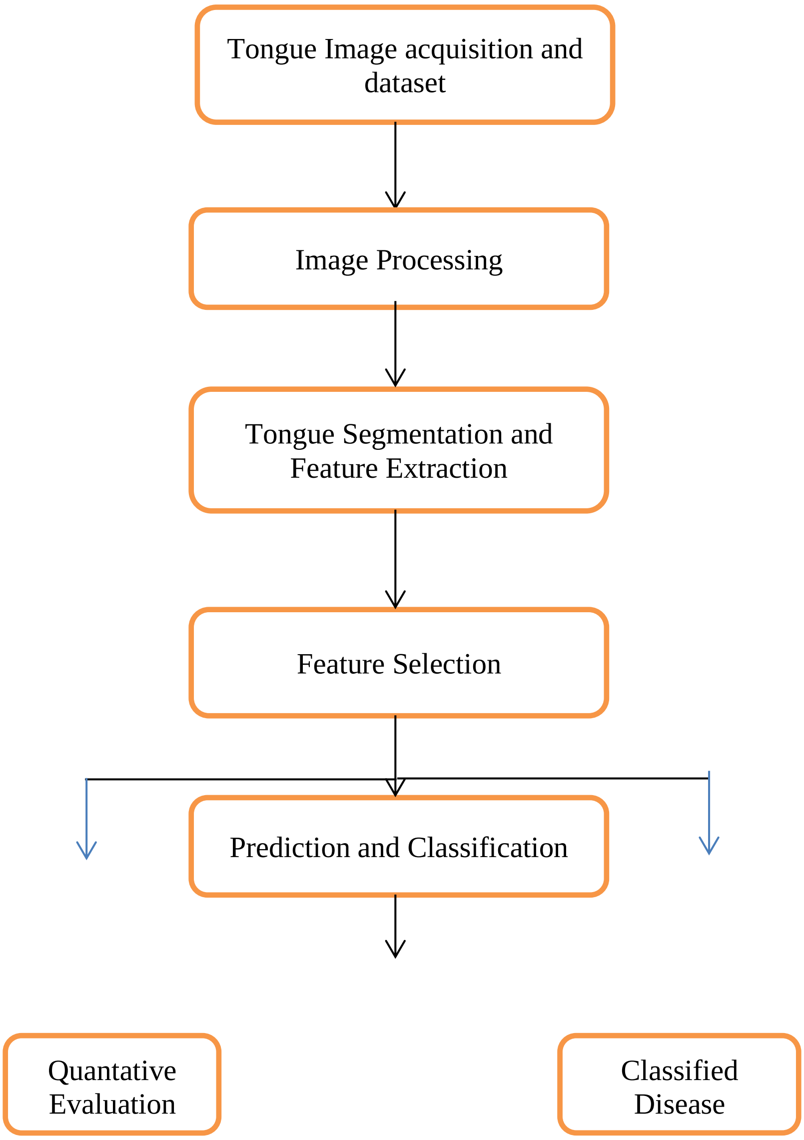

Figure 3.Basic Architecture for Tongue Diagnosis System

Tongue Diagnosis Using Deep Learning

More neural network layers are used in deep learning, a subfield of machine learning. A single-layer neural network can also make a decision prediction, but the performance and accuracy both improve with additional layers. It makes judgements based on taught information and uses various learning processes in an effort to mimic the human brain. Automation, analytical thinking, and other AI applications rely on it. Automatic Tongue Diagnosis (ATD) is being made possible with the use of the sensors currently installed on smartphones, the application's dynamics, machine learning models, and expertise modules. As a result, strategies, machine learning tools, and CDSS reliant on tongue analysis are inadequate, and their recovery is necessary. Our primary goal is to analyse the benefits of incorporating tongue analysis and provide research that leads to a system that is efficient and requires no human intervention. In general, the research gap and the intended goal may be identified using the benefits and possibilities of prior approaches. While more advanced CDSS is required, newly created CDSS may improve healthcare by linking medical services with health information to help people make better decisions. A variety of feature extraction techniques were created and used with the aim of tongue image diagnosis. These models have successfully included useful information about fundamental properties including shape, colour, texture, and orientation. To detect illnesses using tongue picture analysis, automated artificial intelligence-based machine learning and deep learning models are still required, despite the fact that there are a few alternative techniques to analysing tongue images. Aiming to classify illnesses based on photographs of the tongue, this research employs convolutional neural network (CNN) models grounded on artificial intelligence to construct an effective model for this task.

Use of the HELM classifier in a tongue diagnostic system is the main topic of this essay. Unfortunately, the method's training and testing performance are hindered by its high computational complexity. Consequently, this chapter uses deep learning models to enhance tongue diagnosis. Using a Deep Learning Convolution Neural Networks (DLCNN) classifier, this study aims to apply the Tongue-Net model to the task of illness classification, specifically to the following categories: Healthy, Appendicitis, Bronchitis, Gastritis, Heart disease, and Pancreatitis. First, the sounds in the tongue photos are removed using FNLM, which also enhances the colours. Additionally, colour moments and LBP, GLCM descriptors are used to extract joint texture and colour characteristics from the preprocessed picture. When all characteristics have been retrieved, DLCNN is used to categorise the illnesses.

DLCNN Based Tongue Diagnosis

Predicting diseases from photographs of the tongue is challenging because of the wide variety of structures and colours seen in these images. Consequently, the use of hybrid machine learning models for illness prediction using pictures of the tongue is the main emphasis of our study. The suggested Tongue-Net model's architecture is shown in Figure 4. The input picture sizes are first normalised using the FNLM preprocessing technique. Additionally, this process takes care of the issues with colour lighting and noise reduction. Additionally, colour moments are used to derive means, skewness, and standard deviations from preprocessed pictures. Texture characteristics such as Energy, Contrast, Entropy, Correlation, and Homogeneity may also be extracted using GLCM. Extraction of shape-based attributes is another usage of LBP. Lastly, the retrieved characteristics were fed into a DLCNN classifier, which was then used to categorise the various disorders

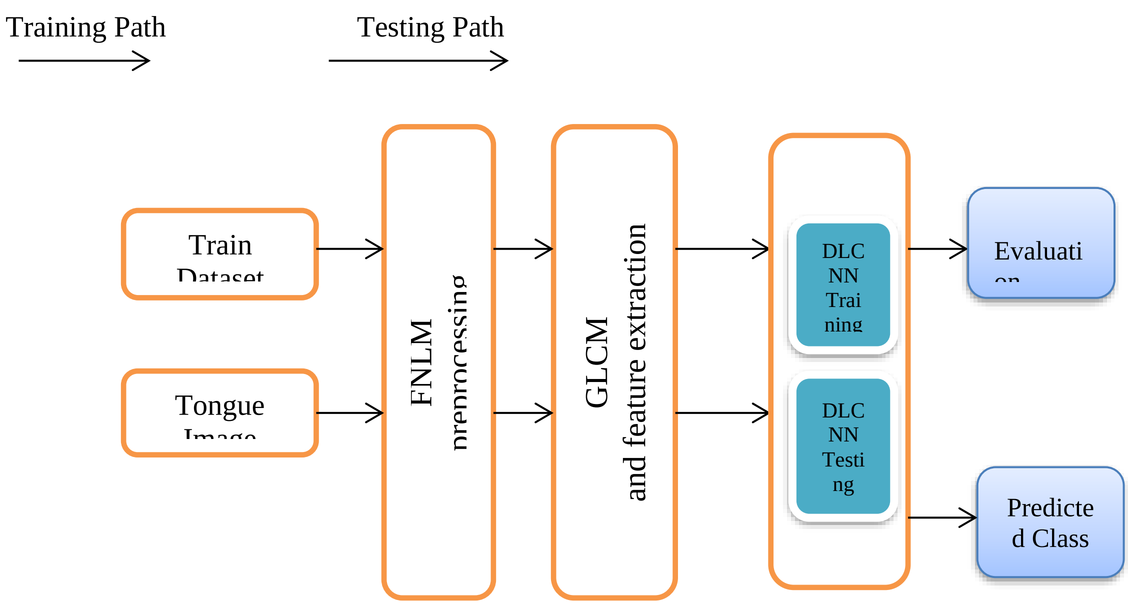

Figure 4 Proposed Tongue-Net Architecture

Among the many illness categories that the suggested Tongue-Net model may anticipate are Healthy, Appendicitis, Bronchitis, Gastritis, Heart disease, and Pancreatitis..

Pre-processing: The FNLM effectively eliminates various types of noise from photographs of the tongue. Tongue pictures' contrast, brightness, contrast, and color-based statistical properties are further enhanced by FNLM. The presentation includes a thorough description of FNLM.

Feature extraction: Features are the images' statistical qualities; they include the images' colours, shapes, entropy, and other prohibited attributes. Classification accuracy may be enhanced by well-chosen feature extraction. Colour characteristics based on mean, skewness, and standard deviation, texture features based on GLCM, and form features based on LBP are all extracted using the suggested Tongue-Net model. The in-depth evaluation of GLCM feature extraction and the colouring feature extraction.

LBP feature extraction: Among its many impressive features are rotation and greyscale invariance, making the LBP operator a go-to tool for texture description. Additionally, it fixes the problem of light fluctuations to a considerable degree, which makes it a top operator.

Figure 4 shows that the first LBP operator compares the grey values of each neighbouring eight-pixel point one by one, with the threshold value being the pixel value of the centre point in a 3x3 window area. The 3x3 matrix format is used to display this. For values of 0, it means the points around the centre point are not as important as the centre point; for values of 1, it means the opposite is true. After then, the LBP operator will convert the 0s and 1s from each pixel into a decimal value that stands for the value of the central pixel at this same moment. If the current centre point's pixel value is not met, the operation is repeated.

2. Conclusion

A major step forward in medical diagnoses has been achieved by this study's Computer-Aided Tongue Diagnosis method, which is based on Machine Learning. We have developed a technology that uses machine learning and deep learning to help with accurate disease forecasting and has the potential to revolutionise healthcare delivery by making it more efficient, accessible, and constantly improving. We hope that in the future, as we develop and enhance this system, innovative diagnostic tools will be easily accessible to help healthcare providers and patients all around the globe. In order to improve the diagnosis process, further work will entail increasing the variety of tongue pictures and conditions in the dataset, improving the model architectures further, and investigating the possibility of integrating new modalities like patient history and symptoms. In addition, we want to explore the system's potential for integration into all-encompassing telemedicine systems and its usefulness for a wider variety of diseases.

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