Arogya -An intelligent Ayurvedic herb management platform

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***Abstract*—Ayurvedic means a science of life and well-being with its unique approaches to social and spiritual life. Especially in Sri Lanka we have our own set of rare ayurvedic herbs which have been utilized by generations as medicinal treatments for a variety of diseases. Absence of specialists in this area makes proper identification as well as classification of valuable herbal plants a tedious task, which is essential for better treatment. Hence, a fully automated system for herb detection and classification, information visualization regarding them and tracking geographical locations of newly identified plants is highly desirable. There are existing applications which can identify plants with low prediction accuracies, as well as to give information regarding them. However, these applications are based on foreign plant data sets that do not include valuable herbs and shrubs with medicinal qualities. Hence this research proposes a centralized social media application unique to medicinal plants, which can perform all these functionalities in both online and offline approach. Here, a new ayurvedic plant dataset prepared from scratch, and preliminary results for classification of 5 types of herbs, compared with several CNN models based on transfer learning are presented. Experimental results indicate Marker-based Watershed algorithm as the best leaf detection algorithm in a complex background, VGG-16 as the best CNN classification model which reached a promising testing accuracy of 99.53%, and Seq2Seq LSTM model as the best deep learning model with optimum accuracy in abstractive information summarization.**

***Keywords*— abstractive information summarization, ayurvedic medication, classification, detection, geographical information system, transfer learning**

I. Introduction

Ayurveda is an ancient medicinal system evolved in India around thousands of years ago, still followed by many people as it is purely natural and has no side effects [1]. It is very relevant from ancient to this most modern time because of its power to cure chronic diseases [1]. Ayurvedic medicine mainly focuses on the Ayurvedic herbal plants & their Ayurvedic medicinal value. Accordingly, every plant on earth has some medicinal value, so it is important to protect the plant and identify its medicinal values [2]. Almost all general diseases can be cured through Ayurveda using parts like fresh leaves, flowers, roots, barks, fruits and extracts, gemstones, and minerals of shrubs and herbs around us. So, the knowledge regarding ayurvedic plants passed down through generations should be preserved and protected.

The World Health Organization (WHO) in 2009 states that 80% of the people worldwide still depend on Ayurvedic botanical drugs or medicine. The health-conscious today is searching for effective alternatives to the spiraling costs and side effects that result from the use of modern medicine [1]. Sri Lankans, in the last couple of millennia, have made use of the "user-friendly and traditional medicine – Ayurveda" which the top 75% of the island's inhabitants relies on due to its credit on natural and valuable medicinal plants, herbs and oils [1]. They have significant contributions towards human lives and play a leading role in the welfare and health of the global public.

Computer vision as well as image processing techniques provide promising results for automated classification of medicinal herbs. But, identifying a medicinal plant with required essential herbal values is still one of the foremost challenging tasks[3] which plays a key role in ayurvedic medicine preparation. Additionally, accurate data sources, acknowledgement of the locations of their growth, as well as supplying reliable proved medical recipes for diseases with specialized categories are important for many parties who are involved in the preparation of ayurvedic medicines [3]. But absence of expert taxonomists is a major concern in this field. Even though herbal medicine lacks side effects when compared with synthetic drugs, treatment using an incorrectly recognised herb might lay claim to the patients' lives. Hence, a fully automated system that satisfies all the above-mentioned requirements regarding the local herbs is inevitable at this point in time.

Hence, the proposed solution is to develop a centralized social media platform (android mobile application) unique to herbal plants, which allows users to detect and classify a group of selected valuable ayurvedic plant species accurately, based on the photograph of the plant part (leaf, root, fruit, etc) as the basic functionality. Additionally, an abstractive summary description of the identified herb's medicinal properties, biological value, as well as reliable information sources about remedies and recipes for specific diseases associated with those plants are provided. The normal functionalities of a social media platform like creating user accounts, publishing posts only related to herbal plants, liking, commenting, and sharing them, and dynamic search with either words or web are also available with this application.

Additionally, the user is capable of adding the locations of herbal plants into the map and track locations (availability and growth) with the aim of preservation of valuable Ayurvedic plants worldwide. So, others can use the locations of previously tracked plants, in order to know about rare and unknown species which are used as ingredients in medical recipes. Therefore anyone without prior knowledge also will be able to identify ayurvedic plants hopefully and use them properly in their medications. On a mobile device, the Ayurveda plant detection has to be done with time, battery life critical manner, especially when it has to be done in a forest area. In the proposed system the whole identification process takes place on mobile devices and it doesn't require the internet. Therefore, this will be a great solution to identify Ayurveda plants in deep forest areas, where mobile network coverage is not available. The development strategy and methodology used in this approach will be able to be used and extended to identify any ayurvedic herb furthermore.

The rest of the paper is organized as follows. Section II will discuss some related work to the system. Section III will be mainly focussed on the methodology as well as the main functionalities of this system. The experimental results obtained, as well as the analysis and discussion of them will be elaborated in Section IV, and finally the research work will be concluded in Section V.

II. RELATED WORK

Novel technologies are emerging in the area of image processing frequently, especially in image segmentation. This research begins with image segmentation. The user has to upload an image of a plant part and then using image segmentation techniques its leaf, fruit or root (objects) are detected. Many researches have been done under object detection and segmentation over several past decades. The research paper [6] presents automatic identification of fruits within complicated environmental factors such as lighting variability, branch, and leaf occlusion and tomato overlap. An enhanced tomato detection model called-Tomato, based on YOLOv3, is proposed to solve these problems. A dense architecture is integrated into YOLOv3 to promote the reuse of features and to help learn a more compact and precise model. The research paper [7] presents object detection to spatially segregated bounding boxes and associated class probabilities as a regression problem. In one evaluation, a single neural network predicts bounding boxes and class probabilities straight from full images. Since the entire detection system is a single network, the performance of the detection can be optimized end to end directly. The architecture of the mode is very fast and images are processed in real-time at 45 frames per second. And also processes a stunning 155 frames per second while still doubling the map function value rather than other object detectors.

Watershed algorithm is one of the most popular segmentation algorithms used in the processing of medical [8] and material science images [9]. This is based on the depiction of a gray picture as a topographical relief that is saturated with water, where watersheds separate water areas from various basins. The research paper [10] presents the concept of texture gradient and used to establish an effective watershed segmentation strategy for common images in light of the boundaries of strength and texture. In addition, a new marker option calculation is performed to test the over-division problem. The research paper [11] introduces a new mathematical morphology based watershed algorithm for cellular image. The watershed algorithm based on the marker enhancement segmentation approach incorporates the concept of morphological reconstruction during pretreatment. The approach can be more accurate in segmentation results compared to the original watershed method segmentation.

According to many researches carried out regarding the problem of medicinal plant classification [13], there are existing applications which can identify plants with low prediction accuracies. In 2019 in the study [14], an approach has been proposed which depicts a combination of deep architectures together. Deep features have been extracted from the leaves using the fc6 layer of AlexNet and VGG16 models. After that, dimension reduction of deep features using the Principal Component Analysis (PCA) method has been applied efficiently and the best differentiated features were acquired. Finally, performances against classifications have been calculated using the K-Nearest Neighbor (KNN) algorithm. Flavia and Swedish, which are two popular plant leaf datasets, have been used for the testing of the system proposed. According to the experimental results, accuracy scores 99.42% and 99.64% were achieved for Flavia and Swedish leaf datasets respectively.

In 2019 in the study [3], a deep learning based Convolutional Neural Network (CNN) model has been proposed to a system named AyurLeaf, in order to classify herbs using leaf features which included shape, size, color, texture etc. In addition, a standard dataset for medicinal plants has been proposed by this research work, which are habitually visible in various regions of Kerala. This dataset contains samples of leaves from 40 medicinal plants. A deep neural network inspired by Alexnet is utilized for the efficient feature extraction from the dataset. Finally, the classification is performed using Softmax and SVM classifiers. A classification accuracy of 96.76% has been achieved upon 5-cross validation, by their proposed model on the AyurLeaf dataset.

The proposed system Arogya is capable of generating dynamic summaries regarding the identified medicinal plants. So, the system has to work with the online database, whenever the web pages get updated, the generated summary also should be adjusted in order to the current version of the changed website page. Hence it is a kind of real time information extraction, users also will get updated automatically. Currently, the existing systems are just managing the offline database of their own system, so the information will not be changed according to the timeline. So, the users will not get updated with real-time information of that particular medicinal plant. In 2019, the paper [4] extends the state-of-the-art abstractive summarization architecture for multi-document summarization. This produces a comprehensive summary on a topic by combining the abstractive and extractive summarization approaches in a cascade. The state-of-the-art approach for abstractive summarization using the pointer-generator model is limited to single-document summarization. Summarization of multiple news articles on a topic can be handled one by one independently which results in multiple summaries for the same topic with possible redundancy. In order to avoid redundancy, the authors propose extractive summarization of the 6 multiple summaries as the second phase in the proposed cascade framework. The effectiveness of the framework is established using the ROUGE metric.

In 2018, the paper [5], presents a multi-document text summarization scheme using an unsupervised deep learning algorithm along with fuzzy logic. Feature matrix with seven features from the set of sample datasets from DUC2002(Document ID: AP880911-0016). The feature matrix is applied through the various levels of the RBM and finally, the efficient text summary is generated. The result indicates that this method generates efficient text summary when compared to previous methods based on evaluation metrics.

III. METHODOLOGY

In this research, the image of the leaf/digested root/fruit scanned using the application acts as the input for this phase.

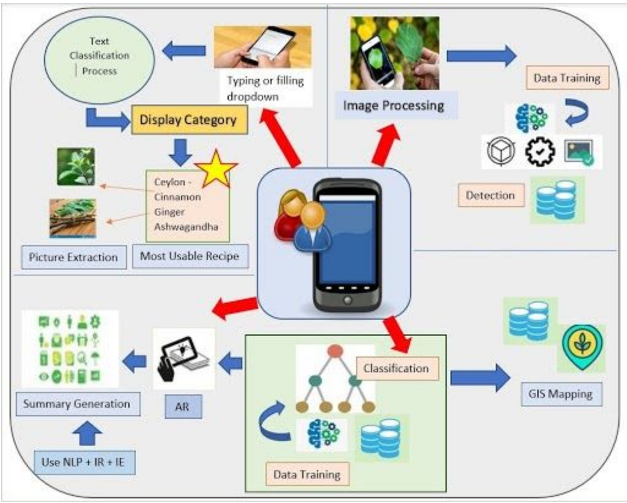

Fig 1: High Level Architecture Diagram of overall system

A. Selecting the most accurate and the highest performance segmentation technique using experimental outcomes

The system provides a way to upload an image of the plant part to be identified. Detecting the objects accurately is more important because it helps the classification process to do a better job using a leaf, fruit or root (any plant part). In addition, detecting objects from complex and noisy backgrounds should also be done accurately, especially in this scenario. Therefore, much attention was given to detect the specific object accurately at the beginning. In order to achieve this objective, it was experimented with YOLO and marker-based watershed algorithms and the most accurate one was selected based on the results. The algorithm applies the entire image into a single neural network, then splits the image into regions and projectes boundary boxes and probabilities for each region [6]. But there were some limitations while applying the algorithm. It struggled to detect tiny objects that appeared in groups and it sometimes failed to generalize new or uncommon aspect ratios or configurations.

One of the most complicated operations of image processing was to distinguish touching objects in image. The watershed segmentation is often applied to this issue. Due to noise, direct application of the watershed segmentation caused over-segmentation. Markers were used as an approach to control over segmentation. This image segmentation algorithm proposed here was capable of segmenting the images with minimum limitations to under and over segmentation. This proposed marker-based watershed segmentation provided several advantages such as it required low computation time, and provided closed contours, fast and simple.

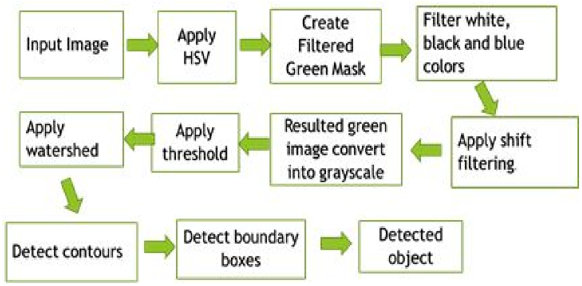

Fig 2: Proposed Marker-based Watershed Algorithm

B.*Classification of Ayurvedic plants using transfer learning based on deep CNN using a mobile application in an offline approach*

Main research areas of this component relied on the key pillars of deep learning, transfer learning based on deep CNN and data augmentation. Target was to analyse several deep CNN models with the acquired training and testing data from scratch, get the final testing accuracy from each in order to compare and achieve the model with the highest accuracy, and then to use it as the finalized model in the herbal plant classification purpose in Arogya, based on images as the input from the mobile camera module.

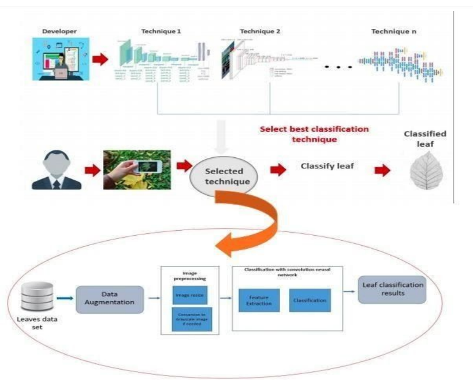

Fig 3: High Level Architecture Diagram for herb classification

After acquiring the images of leaves/fruit/digested root of the selected Ayurveda plants, they were labelled and annotated using "VGG Image Annotator" tool for multi-class classification, by forming 6 classes. After the preparation, transfer learning based on deep CNN was used on the prepared image set for processing them using TensorFlow. When taken as overall, a sample of 1348 images were prepared, where 48%, 26% and 26% of that were used as training, testing and validation splits, without data augmentation. However, training a model from scratch is too costly. To overcome this challenge transfer learning was applied in the Ayurvedic dataset. The proposed identification method was based on running a CNN.

After that, the dataset was retrained on the available neural network CNN architectures, then was fine-tuned from pre-trained weights and then the best technique with the highest accuracy was selected. While the training dataset was augmented, testing and validation datasets were not augmented for higher accuracy purposes. Then, the selected re-trained model with highest accuracy was fine-tuned using data augmentation techniques on the labeled dataset and hyper-parameter tuning. It was re-trained with the dataset using Keras. Finally, the re-trained model was converted for deployment on mobile devices with Goggles' TensorFlow Lite.

C. Abstractive web page information summarization on Ayurvedic plants using a mobile application in an online environmental approach

Main research area of this component was based on natural language processing techniques. Target was to extract dynamic information from multiple web pages and generate a summary on ayurvedic plants. So, in order to achieve this goal, many techniques were followed to select the best model out of them. Thus, several existing algorithms were analyzed, and accuracy was tested in order to select the suitable algorithms to extract the required information from dynamic web pages to generate a summary.

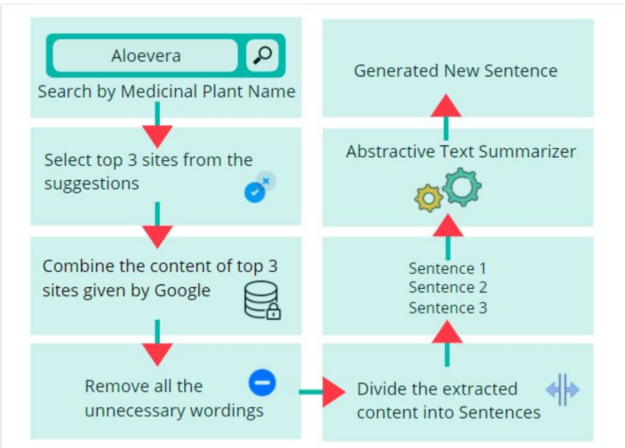

Fig 4: High Level Architecture Diagram for Multiple web pages Text Summarization

The process of text summarization can be defined as generating an incisive and communicative synopsis while conserving the main content of the description and the overall outline. In general, for the process of text summarization, two main approaches are being executed called Extractive Summarization and Abstractive Summarization. As the methodology for this research, Abstractive Summarization was used. Instead of existing sentences, new sentences were generated which were totally differentiated from the original text. In contrast, what extractive summarization did was prepare the summary with the most important sentences which were extracted from the original text.

According to our working plan, the input was a set of descriptions of medicinal plants which were extracted from highly ranked multiple websites and the output was a short summary of sequence of words. Hence, this was modeled as a Many to Many Seq2Seq problem. Encoder and the Decoder are the two major components of a Seq2Seq model. In this research component Long Short Term Memory was used as the encoder and the decoder. The Encoder-Decoder was set in two phases as training phase and Inference phase. As the first step Encoder and the Decoder were set in the training phase. The model was trained to predict the target sequence offset by one timestep. The way Encoder and the Decoder were set was as follows: the whole input sequence was read by the long short term memory model at each timestep, one word was counted. Information at each timestep was processed and related information present in the input was captured. Decoder also worked as a Long Short Term Memory network. Entire target sequence was read word by word to predict the same sequence offset by the decoder. Decoder was capable of predicting the next word in the sequence given the previous word. At the inference phase after doing training, the model was evaluated on a new source sequence. Target sequence was an unknown one. Inference Architecture was to be set up to decode a test sequence. At the final stage, the user retrieved a summarized paragraph on the specific Ayurvedic plant.

IV. RESULTS AND DISCUSSION

A. Dataset

A newly captured, prepared and annotated Ayurvedic plant dataset from Sri Lanka was trained on the Convolutional Neural Network (CNN) from scratch. Among many herbal plants, 5 were chosen to analyse further in detail, and the images of the leaves/fruits/digested roots(dataset) were collected from Ayurveda Research Institute at Navinna, alternative medicine websites and blogs related to Sri Lankan herbal plants and social media, creating a noisy dataset. A set of 1348 leaf images were retained, where 883, 235 and 230 images were used for training, validation and testing purposes respectively.

B. Experimental Results

Among the YOLO and the proposed marker-based watershed algorithms, the proposed marker-based watershed algorithm was proved as the best detection algorithm for the leaf, even if the leaves were in a complex background. Results are shown in below:

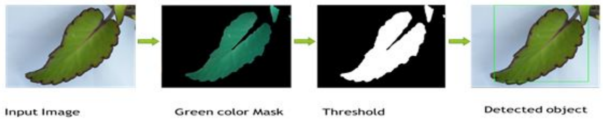

Fig 5: Leaf detection in simple background

Fig 6: Leaf detection in complex background

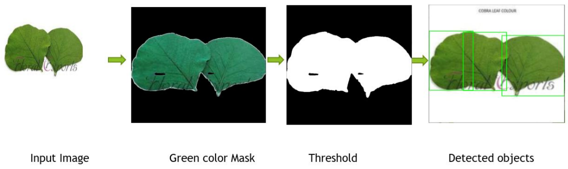

Fig 7: Detection of overlaps leaves

Then, the detected plant part was used for the classification purpose.

TABLE I. Comparison of accuracies for the selected CNN models in herbal plant classification

CNN Architecture	**Final testing accuracy**
InceptionV3	56.76%
MobileNetV2	63.58%
InceptionResNetV2	82.77%
CNN model trained from scratch	85.63%
Xception	86.01%
DenseNet121	89.12%
ResNet50	98.92%
VGG16	**99.53%**

According to the comparison, the pre-trained model VGG16 with a testing accuracy of 99.53% was chosen as the model with the highest accuracy and was fine-tuned with data augmentation techniques and with hyper-parameter tuning. Building of the finalised CNN model with the highest accuracy can be explained stepwise as follows.

I. Created the base model from the VGG-16 model, which is pretrained on the ImageNet dataset.
II. Extracted the features through freezing the convolutional base.
III. Added a flatten layer, which did not affect the batch size.
IV. Added a dense layer, with 1x256, with the activation function as 'relu' (adding of dense layers was decided by considering the number of classes)
V. Added a dense layer for 6-class classification, with the activation function as 'softmax'.
VI. Compiled the model before training it - here, 'categorical_crossentropy' was used as the loss function, 'RMSprop' as the optimizer, (1e-4) as the learning rate and 'categorical_accuracy' as metrics.
VII. Training and testing datasets were loaded, where training dataset was augmented according to different augmentation techniques, while testing dataset was not augmented due to valid accuracy purposes.
VIII. Finally, the dataset was trained for 100 epochs, with using the number of steps per epoch training as 100, and the number of steps per epoch testing as 50.

```
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Model)                (None, 3, 3, 512)         14714688
_________________________________________________________________
flatten (Flatten)            (None, 4608)              0
_________________________________________________________________
dense (Dense)                (None, 256)               1179904
_________________________________________________________________
dense_1 (Dense)              (None, 6)                 1542
=================================================================
Total params: 15,896,134
Trainable params: 15,896,134
Non-trainable params: 0
```

Fig 8: Finalized classification model summary

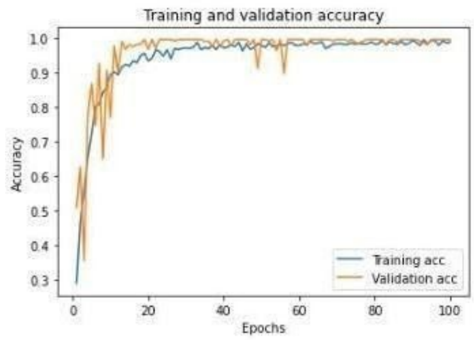

Fig 9: Finalized model performance accuracy graph

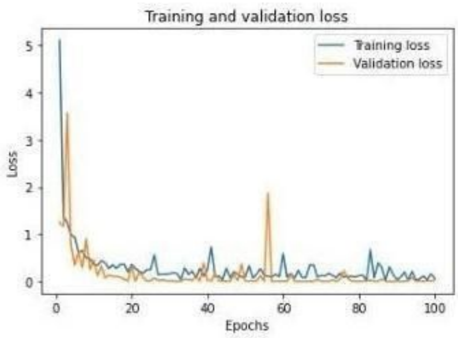

Fig 10: Finalized model performance loss graph

TABLE II. Experimental classification accuracy class wise

Plant Class	**Classified amount**	**Misclassified amount**	**Accuracy**
Akkapana	40	0	100%
Cinnamon	36	4	90%
Katupila-leaf with fruit	36	4	90%

Kohomba	40	0	100%
Turmeric	38	2	95%
Turmeric - digested root	40	0	100%
Average			**95.83%**

The following graphs depict clear evidence to prove the experiment results that the Seq2Seq LSTM model obtained the highest accuracy. The graphs indicate the word count comparison between, the generated summary and the customized text which was extracted from the multiple web pages dynamically.

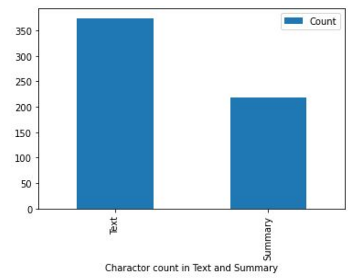

Fig 11: Instance 1 - Word count of Generated Summary in comparison to Customized text

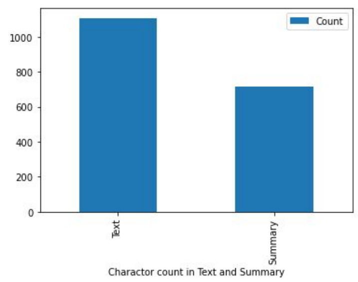

Fig 12: Instance 2 - Word count of Generated Summary in comparison to Customized text

V. Conclusion

The purpose of this research is to develop a centralized social media application which is mobile-based and unique to herbal plants. This solution would be a great chance for those who are keen to learn and use Ayurveda medicine and plants, but who do not have prior knowledge about the specific domain. The application mainly creates awareness among common people about Ayurveda plants, their medicinal usage and value, and about their growth and availability throughout the country. This proposed system has been tested in various situations and it is capable of providing the most reliable and accurate output to the user. According to the main research components focussed, it has been experimentally proved in this research that the most suitable algorithm for plant detection based on our dataset prepared from scratch is Marker-based Watershed algorithm, and the most accurate CNN pre-trained model used for classification purpose is VGG-16, which achieved a testing accuracy of 99.53%. The results are highly promising, reaching over 99% accuracy using the VGG-16 model. Additionally, the Seq2Seq LSTM model which is a deep-learning model has been proved as the best model with optimum accuracy in the purpose of abstractive information summarization. This application is currently built only in English. Further, this can be applied in native languages such as Sinhala and Tamil. Since the system is designed only as a mobile application, later can be improvised to a web application with the same functionality and content. Additionally, the development strategy and methodology used in this approach will be able to be used and extended to identify any ayurvedic herb worldwide furthermore, and if the user ends up with doubts and clarifications regarding this procedure, this application can be facilitated with consultation help from Ayurveda doctors.

References

[1] Ayurveda - [Lakpura]
Available: https://lanka.com/about/interests/ayurveda/
Accessed: February 15, 2020. [Online]

[2] B. R. Pushpa, C. Anand, and P. Mithun Nambiar, “169Ayurvedic plant species recognition using statistical parameters on leaf images,” *Int. J. Appl. Eng. Res.*, vol. 11, no. 7, pp. 5142–5147, 2016.

[3] M. R. Dileep and P. N. Pournami, “AyurLeaf: A Deep Learning Approach for Classification of Medicinal Plants,” *IEEE Reg. 10 Annu. Int. Conf. Proceedings/TENCON*, vol. 2019-October, pp. 321–325, 2019, doi: 10.1109/TENCON.2019.8929394.

[4] A. K. Singh and M. Shashi, “Deep Learning Architecture for Multi-Document Summarization as a cascade of Abstractive and Extractive Summarization approaches,” *Int. J. Comput. Sci. Eng.*, 2019, doi: 10.26438/ijcse/v7i3.950954.

[5] S. S. Lakshmi and M. U. Rani, “Multi-Document Text Summarization Using Deep Learning Algorithm with Fuzzy Logic,” *SSRN Electron. J.*, 2018, doi: 10.2139/ssrn.3165331.

[6] G. Liu, J. C. Nouaze, P. L. T. Mbouembe, and J. H. Kim, “YOLO-tomato: A robust algorithm for tomato detection based on YOLOv3,” *Sensors (Switzerland)*, vol. 20, no. 7, pp. 1–20, 2020, doi: 10.3390/s20072145.

[7] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, “You only look once: Unified, real-time object detection,” *Proc. IEEE Comput. Soc. Conf. Comput. Vis. Pattern Recognit.*, vol. 2016-December, pp. 779–788, 2016, doi: 10.1109/CVPR.2016.91.

[8] T. Atta-Fosu, W. Guo, D. Jeter, C. M. Mizutani, N. Stopczynski, and R. Sousa-Neves, “3D clumped cell segmentation using curvature based seeded watershed,” *J. Imaging*, vol. 2, no. 4, 2016, doi: 10.3390/jimaging2040031.

[9] E. V. Myasnikov, “Hyperspectral image segmentation using dimensionality reduction and classical segmentation approaches,” *Comput. Opt.*, vol. 41, no. 4, pp. 564–572, 2017, doi: 10.18287/2412-6179-2017-41-4-564-572.

[10] R. Hill, C. N. Canagarajah, and D. R. Bull, “Watershed Transform,” *IEEE Trans. Image Process.*, vol. 12, no. 12, pp. 1618–1633, 2003.

[11] W. Bin Chen and X. Zhang, “A new watershed algorithm for cellular image segmentation based on mathematical morphology,” *2010 Int. Conf. Mach. Vis. Human-Machine Interface, MVHI 2010*, pp. 653–656, 2010, doi: 10.1109/MVHI.2010.55.

[12] J. W. Tan, S. W. Chang, S. Abdul-Kareem, H. J. Yap, and K. T. Yong, “Deep Learning for Plant Species Classification Using Leaf Vein Morphometric,” *IEEE/ACM Trans. Comput. Biol. Bioinforma.*, vol. 17, no. 1, pp. 82–90, 2020, doi: 10.1109/TCBB.2018.2848653.

[13] B. S. Anami, S. S. Nandyal, and A. Govardhan, “A Combined Color, Texture and Edge Features Based Approach for Identification and Classification of Indian Medicinal Plants,” *Int. J. Comput. Appl.*, vol. 6, no. 12, pp. 45–51, 2010, doi: 10.5120/1122-1471.

[14] B. Muhendisligi, B. Oniversitesi, and B. Muhendisligi, “Combination ofDeep Features and KNN Algorithm for Classification ofLeaf-Based Plant Species.”