Journal of Theoretical and Applied Information Technology
31st May 2017. Vol.95. No 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A NOVEL AUTOMATED METHOD FOR COCONUT GRADING BASED ON AUDIOCEPTION

[1]PRASHANTH THOMAS, [2]Dr. ANITA H B
[1]PG Scholar, Department of Computer Science, Christ University, Bengaluru, Karnataka, India
[2]Assistant Professor, Department of Computer Science, Christ University, Bengaluru, Karnataka, India
E-mail: [1]prashanththomas93@gmail.com, [2]anitahb@yahoo.com

ABSTRACT

The quality of the coconuts used for various purposes is of utmost importance. Demand for better quality products is constantly on the rise due to the improvements in the standard of living of people. There is a possibility that a bad coconut goes unnoticed by the traders, as it is hard to decide if a coconut is good or bad by relying only on its external appearance. Traditionally, quality assessment is carried out manually with the help of three senses; sight, hearing and smell. In the proposed work, a sound processing technique is used in an attempt to automate this process which overcomes the drawbacks of manual processing, which can be used in large godowns and warehouses. This proposed method provides the quality assessment of the coconut purely based on audioception. While creating the database, coconuts varying in size, shape, color and water content were taken from several places as a source for the dataset. Features are extracted from the sound pattern produced by the dropped coconut, which forms the basis for classification. Sequential Minimal Optimization (SMO), Dagging and Naive Bayes classifiers were used and the results obtained were found to be encouraging.

Keywords: *Sound Processing, Coconut Grading, Sequential Minimal Optimization (SMO), Dagging, Naive Bayes, Fast Fourier Transform*

1. INTRODUCTION

Audioception refers to the ability to perceive or hear a sound. These sound waves are nothing but some sort of disturbances which travel through a medium. These disturbances are termed as vibrations. They hit the eardrum, which then traverse to the brain using auditory nerves. It is only then that the brain perceives the vibrations as sound. The human brain then tries to relate the sound produced to form some sensible data.

Sound based techniques are used in various other fields of work thus far; medicine, industries and the military are but a few. In the field of medicine, ultrasound tests are done in order to view the internal organs of the human body, it is also a test performed on pregnant women to check if there is any abnormality in the fetus. In industries, ultrasound is used to check the buildings structure. Thickness of metal and plastic pipes can also be measured. Its major use is to check for cracks or damages in various items used for construction. SONAR is a good application of sound in the military; it is used to detect enemy ships and submarines under water. Ultrasound is also used to understand the surrounding environment. The SONAR uses concepts similar to that of radio waves along with the use of the Doppler Effect.

The proposed work plays its part in the field of agriculture utilizing the concept of digital sound signal processing with a proposed mechanism involved. In this paper the power of sound is used to solve a problem in the field of agriculture. It is a novel approach for coconut grading and no such prior work has been done to the best of our knowledge.

Here the proposed work uses the properties of sound to classify if a coconut is usable or not. Here we deem a coconut usable if it has good amount of water content within it and is not cracked or rotten.
The coconut palm (Cocos nucifera linn) is the most treasured palm in the field of agriculture. All aspects of the tree is valuable to human life for some reason or the other. Consequently, the coconut palm is endearingly called "kalpavriksha" which means the tree of heaven. The copra got by drying the kernel of coconut is the wealthiest wellspring of vegetable oil containing 65 to 70 percent oil. The proposed work considers only on

the coconut. The good coconuts can be used by the people. The older coconuts can be used for making oil. The bad rotten ones can be discarded. Perceiving if a coconut is good or bad based on its exterior appearance is a hard task. The coconut might be rotting inside, but at the same time its exterior composure still holds good. Thus classifying it in terms of usable or unusable is difficult. A system to help in deciding whether the coconut is good or bad without breaking the coconut is very much required.

From ancient times people used sound to classify the coconut based on the amount of water present inside the coconut. A person would shake the coconut, listen to the water inside the coconut and conclude if it was good or bad. Using sound processing concepts to classify the coconut helps in reducing the tedious job of manually classifying the coconuts.

The proposed approach classifies coconuts based on sound. Firstly, the coconuts will be dropped from a reasonable height with similar or constant constraints and then the sound produced on impact will be recorded. Reasonable features from the sound which help in the classification of the coconut will be extracted and run against predefined threshold values. If the feature set values are lesser than the threshold values, then the coconut is deemed bad or unusable, else it is deemed good or usable.

To the human ear the sound produced by different coconuts on impact with a solid constant object is distinguishable. Keeping the constant environment in mind, the sound produced on impact by a dry empty coconut would be different from a coconut which is fresh and contains a lot of water. The human mind is capable enough to distinguish these two sounds. In this proposed work, the sounds are recorded and classified by extracting suitable feature sets from the sound signal.

2. LITERATURE SURVEY

Sound is a form of energy or vibration which is used in different fields as solutions to a variety of problems. The domain of agriculture and sound processing is a rare combination which is brought about in this paper. The processing of sound signals can be broken down into two, namely speech and sound processing. The proposed work uses methods and concepts from both these techniques.

2.1 Speech Processing

The listener receives speech signals, which conveys useful information. In the lowest levels of abstraction speech can be viewed as a collection of words arranged in a particular format to form a meaningful message. But, at higher levels, the amount of data that can be extracted from speech is simply remarkable. It can give the listener data about the gender of the speaker, whether there was any kind of emotion involved and possibly the identity of the speaker as well. Speech recognition systems try to identify the words spoken in speech, whereas automatic speaker recognition systems aims at extracting features from the speech, which helps in deriving the identity of the speaker[1,2]. Procedures have expanded from human aural spectrogram and comparisons, to simple template matching, to dynamic time-warping approaches, to more modern statistical pattern recognition approaches, such as neural networks and Hidden Markov Models (HMMs). Methods used to extract and recognize different information from the speech signal can also successfully be applied to speaker recognition [3].

A survey regarding automated bird population, provides a large volume of valuable data about species distribution modelling [4]. This modelling requires less expense and effort than human surveys. Classifying bird sounds not only gives information regarding the species of birds, but this can also be used for various other applications like reducing plane crashes triggered by bird collisions. Audio classification systems begin by firstly extracting features related to the acoustics of the audio signal. Such features frequently relate to individual frames (i.e., signals in small segments). For example, the spectrum of a signal frame is a very frequently used feature, where the intensity of the signal is described as a function of frequency. Representing sound which has multiple frames is necessary and the same can be accomplished using a fixed-length vector to describe the sound as a whole. Representing the sound in such a manner allows the application of standard classification algorithms. To construct such a fixed-length feature, a common approach is to first identify interesting frames using segmentation, compute features for those frames, then take the average of the features over all frames [5,6,7]. The proposed work also follows similar methodologies wherein the area of interest is extracted from the sound recorded. This is then converted to a vector of numerical values on which statistical calculations are performed.

Time frequency techniques such as the short-time Fourier transforms, energy distributions and wavelets have commonly been used in bioacoustics signal analysis and identification system. But there have been several shortcomings, for example, the difficulty lies in the implementation of such techniques requiring intensive computation of low cost microcontroller-base systems [8]. In the proposed work a version of Fourier transform is applied on the sound signal produced.

2.2 Sound Processing

Sound processing uses sound waves to traverse and retrieve information about the object. This is done by studying the resultant sound waves reflected by the object. In the field of medicine, ultrasonic techniques have become very important both for diagnoses and for therapeutic modality. From the 1930's, ultrasound has been used in the field of medicine. Now its techniques have been widely used and potential fully recognized. Medical ultrasonics has been rapidly growing and will soon make an impact on clinical medicine. This field provides various opportunities to look into challenging and important engineering problems unique to engineering and biology [9].

With respect to the industrial field, vehicles which can give details regarding the surrounding environment and the terrain is possible by studying the noise generated by the vehicle passing over a specific type of terrain. This experiment used a microphone to record audio which resulted in higher accuracy of noise classification [10]. The proposed work also involves the use of a microphone to record the sound produced by the coconut on impact with a solid granite slab. Also a standard commercial tool specifically built for an application is available for every item on the list. Since any ultrasonic measurement can be analyzed with respect to observations associated with wave amplitude or transit time, general-purpose electronic measuring tools such as digital processing oscilloscopes, computing counters, time intervalometers, peak detectors, etc., can also be used to perform tests and measurements for industrial purposes [11]. Most of the measurements utilize approaches designed to respond primarily to sound speed, but some depend on attenuation effects. Most equipment in use involve intrusive probes, but non-invasive, externally mounted transducers are being promoted in several areas. Both pulse and resonance techniques are widely used.

Millions of people across the world are inflicted with bone fracture injuries every year. Long term healing imposes burdens in terms of socioeconomic and personal costs as well as patient's quality of life. Low-intensity pulsed ultrasound (LIPUS) has gained much attention as a potential adjunctive therapy for accelerating fresh fracture healing. Though this method has proven helpful in healing, its efficacy still remains controversial. Several studies have demonstrated the potential for LIPUS to accelerate fracture healing by altering molecular and cellular mechanisms involved in each stage of the healing process. In simpler terms LIPUS can be expressed as a catalyst which helps induce quicker healing [12].

Ultrasound technology has found its applications in the field of medicine in the form of therapeutic ultrasound which is being used to heal human tissues. Research shows that constantly controlled ultrasound can heal soft tissues at a faster rate [13]. This research has been further carried out in other fields of medicine to determine music's impact on the brain's thinking process. With respect to the proposed work, Ultrasound can also be used to study the inner part of the coconut. This can provide information regarding the inner section of the coconut which can act as an alternative method for coconut grading. But this method would be more expensive. The proposed methodology uses a microphone for audio recording. This audio acts as the base for classification. There is no need for an external system to produce ultrasound to understand the inner structure of the coconut. The equipment required to setup an entire working system to classify the coconuts is less expensive.

The development of SONAR systems was fuelled by the Titanic tragedy in April 1912. Since then it has been in practical use, especially in the turn of 20th century. This system and its derivations can be considered as one of the most developed engineering systems. These systems were largely developed during the World War II because of its active or partial applications in military systems. However, recent applications of SONAR systems can be found the areas of underwater wireless networks. Major research subjects are concerned with detection or classification, tracking and telecommunication tasks. This section discusses about recent research in signal processing for SONAR systems. It also discusses proposed classic and modern approaches for intelligent methods in underwater wireless sensor networks [14]. SONAR signal can be classified into wide range of applications which is varied based on parameters like SONAR's mode of operation, namely active and passive. The applications also depends on the nature of received signal, which can be radiated acoustic noise of marine vessels or a ping's echo from ships and so on. The passive SONAR plays an important role in the modern naval battles. It can detect long range signals and can work secretly in its environment. These advantages of SONAR make it applicable in the areas of underwater surveillance systems to stealthily monitor surface and sub-surface marine vessels. SONAR is used on a larger scale of search to detect objects generally present under the sea. SONAR provides an understanding of the outer structure of an object. In terms of the proposed work, it cannot be used to detect the inner structure of the coconut. But it can be used to detect cracks on the coconut shell. This process involving the use of SONAR is a cost overhead.

3. EXISTING SYSTEM

The current system in classifying coconuts involves a manual approach. Often the rotten coconuts go undetected until their foul odor is smelt. Most of the time, the coconuts are classified only after it is broken based on how it is from the inside. This approach again is a tedious process. The accuracy in classifying the coconuts is lesser when it is classified without being broken and repeating this process on a large scale is time consuming. Replacing this manual process with a self-automated system where it can classify the coconuts only with the outer appearance would be very efficient. From the outside all the coconuts look similar. Due to this it is very difficult to classify coconuts using image processing. So sound processing would be a more optimal method in coconut grading.

4. IMPLEMENTATION

The proposed work aims at classifying coconuts based on sound. The coconuts will be dropped from a reasonable height initially with similar and constant constraints; the sound produced on impact will be recorded. Reasonable features from the sound which help in the classification of the coconut are extracted and run against a database consisting of extracted features. SMO, Dagging and Naïve Bayes classifiers are used to segregate the coconuts into their respective predefined classes.

Compared to the manual process the automated process is prone to lesser number of errors. The manual process of classification requires humans to visually grade a coconut. Perceptions and judgements tend to vary from person to person. Moreover, errors in judgement are bound to happen in such situations. The constraints provided make classification easier.

4.1 Data Collection

The entire database consists of 3 datasets, each consisting of a unique collection of recordings. Initially the entire concept of the proposed work was to classify coconuts as good or bad. But then as a good coconut can have sub classes of classification, Dataset_2 came to be. Similarly the bad coconuts are also sub classified into two sub classes in Dataset_3. The following are the used data sets.

Dataset_1: This dataset consists of a collection of recordings consisting of both Good and Bad coconuts. It consisted of 70 recordings, out of which 40 were Good coconuts and 30 were Bad coconuts. Here Bad coconuts are rotten and the Good coconuts have a nice water content and thick inner layer. This dataset's recordings can be divided into two classes, a class consisting of Good coconuts and a class consisting of Bad coconuts.

Dataset_2: This dataset consists of a collection of recordings consisting of only Good coconuts. It consisted of 40 recordings, the recordings were split into half representing the two sub classes.
This dataset's recordings can be divided into two classes, a class consisting of Good coconuts with good water content and thicker inner meat and a class consisting of Good coconuts with lesser water and a lesser inner meat

Dataset_3: This dataset consists of a collection of recordings consisting of only Bad coconuts. It consisted of 40 recordings, the recordings were split into half representing the two sub classes. This dataset's recordings can be divided into two classes, a class consisting of Bad coconuts with no water content and rotten inner meat and a class consisting of Bad coconuts which are cracked.

4.2 Pre-processing

4.2.1 Mechanical pre-processing

This phase involves a manual processing of coconuts. It firstly would involve the coconut to be dehusked. This can be accomplished manually using a machete, knife or sickle. It can be done mechanically as suggested by Stephen Kwasi Adzimah and Samuel Oppong Turkson [15], where machines are used to dehusk the coconut.

Journal of Theoretical and Applied Information Technology
31st May 2017. Vol.95. No 10

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 1: Husk Removal

Following the mechanical approach of dehusking might not yield complete dehusking. In most cases the crown husk is still left on top with strands of coconut fibre still clinging on. This might have to be manually removed. It must also be noted that fresh new coconuts cannot be taken into consideration, as the shell might still be tender, where the coconut can break or crack on impact. The coconut should have matured in age such that the shell will not crack on impact.

4.2.2 Data pre-processing

In this phase there are certain constraints or configurations previously set, using which the database is constructed. The sound is recorded at 16,000 Htz with a bit rate of about 16 bits per sample. This is a constant constraint throughout the entire recording procedure. The recording should be a mono recording and not a dual recording as it may take more time to process the dual audio files. For the first dataset the cropping happens via code. But for the second and third dataset cropping of the audio file is done manually.

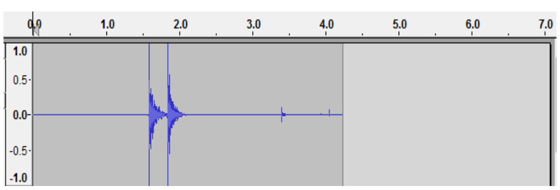

Figure 2: Audio File

For manual cropping, first open the recorded audio file in Audacity, a software tool used to record and edit sound signals. The Fig.2 depicts the sound pattern represented in the recorded file. It shows the wave pattern the duration of the recording and whether it was a dual or a single audio recording.

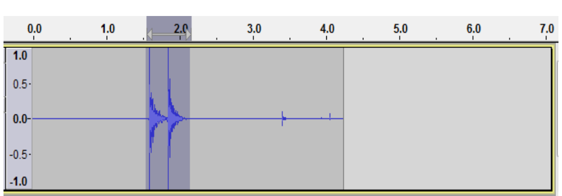

Figure 3: Select Region

As depicted in Fig.3 the required region of the audio file is cropped and resaved in a .wav format which the user will use for classification. Fig.4 represents how the final cropped wave form would appear.

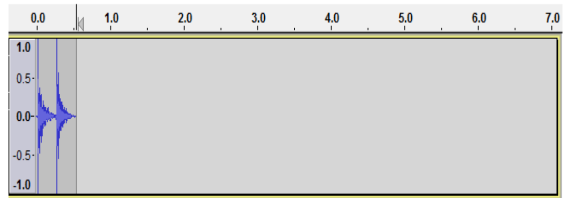

Figure 4: Cropped Audio

4.3 Environmental Setup

Dataset_1: The experiment is performed on a granite slab. It is surrounded with cloth and sponge to dampen any secondary noises which may be produced. A mic is placed at a constant distance for recording the sound. This mic is not to be tampered with until the experiment is done. Changes in the mic's position might lead to changes in feature values.

Dataset_2 and Dataset_ 3: A static environment setup is to be provided. It should consist of a granite slab surrounded by a soft padding of sponge or cloth. The coconut is dropped on the slab always maintaining a distance of one feet. The padding is to catch the ricocheting coconut. A mike attached to the recording system is placed at a constant distance. The position of the mike should in no way change as it might affect the sound recorded. The mike, the granite slab, the padding used should all be constant throughout the recording session.

4.4 System Work Flow

The coconuts need to be of a standard size and a standard shape. An environment is to be built such that it upholds the following constraints.

- Noise free environment.
- Unchanging recording mechanism.
- Constant environment setup.
- The coconut is dropped onto a granite slab from a constant height of one feet.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

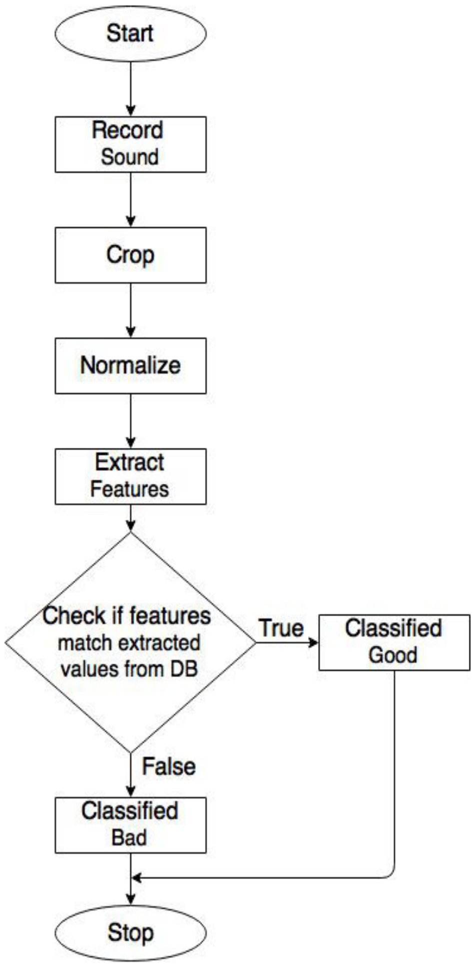

Figure 5: System Work Flow

When the coconut comes in contact with the granite slab, a sound is produced because of the impact. This sound is recorded under uniform environmental conditions. After the sound is recorded, it is cropped and normalised. The microphone will continue recording for about three to four seconds. But out of the entire audio recorded, only a portion of the audio where the actual impact of the coconut was recorded is cropped out. This helps in reducing the overall processing time involved with each audio file. These audio files are then individually considered for feature extraction. After the sound is recorded the coconut is opened and its condition is manually checked. While testing, sound is recorded, features are extracted, classified and the status of the coconuts are noted for verifying the accuracy of the results generated.

4.5 Feature Extraction

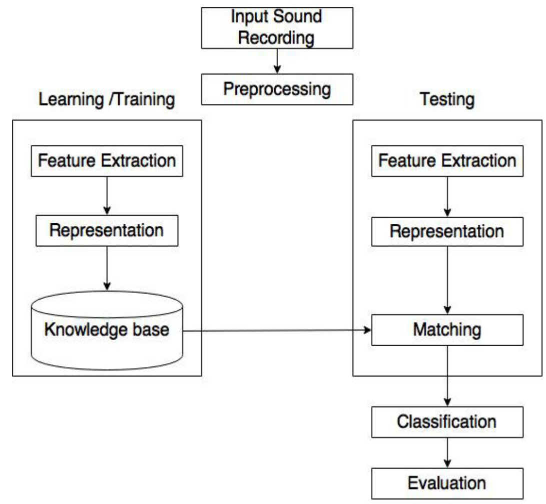

Figure 6. Feature Extraction Procedure

Sound classification analyses features represented in numerical values and it organizes data into categories. Training and testing are the two phases typically employed in classification algorithms. In the initial training phase, characteristic properties of typical sound features are secluded and, based on these, a unique description of each classification category, i.e. training class, is created. In the subsequent testing phase, these feature-space partitions are used to classify extracted features.

Importance is given in the depiction of the training classes. In supervised classification, statistical or distribution-free processes are used to extract class descriptors. The proposed system follows supervised method of classification as the classes are already predefined. Here the Fast Fourier Transform(FFT) acts as the base for all signal related feature extraction. The FFT is a powerful general-purpose algorithm widely used in signal analysis. FFT is used to convert a signal in wave form into spectral information. Most distinguished features can be extracted using Fourier domain.

4.6 Features

Feature_1: The cropped sound signal is considered and a FFT is performed on this signal. The resultant of this process gives us a spectrum which is represented by complex values. The real part of each of these complex values is considered and Standard deviation is performed.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Feature_2: Similar to *Feature_1*, here the mean of the real values is considered instead of the Standard Deviation.

Feature_3: The cropped sound signal is considered and an FFT is performed on this signal. The amplitude of the signal is then found using the following formula:

$$amp_{var} = \max(20 * log_{10}\left(abs\left(fft(y)\right)\right)) \quad (1)$$

where 'y' is the cropped sound signal which servers as input to the fft() function, which performs the FFT of the signal. This is then passed on as input to the abs() function which gives the absolute values of the FFT signal. The max() function gives the maximum value present from a list of values.

4.7 Classifiers

The Weka Knowledge Explorer provides an easy to use graphical user interface that harnesses the power of the Weka software. In the proposed system SMO, Dagging and Naïve Bayes classifiers are used for classification, these classifiers were chosen empirically. SMO classifier gave good accuracy when compared to Dagging and Naïve Bayes classifier.

4.8 Algorithm

The algorithm below defines the entire step by step process involved in feature extraction from the recorded sound signal.

Input: Sound Signal
Output: Feature vector
Method:
Step 1: Isolate only required region of the audio and crop it out.
Step 2: Normalize the cropped audio to a standard format.
Step 3: Perform an FFT on the audio signal.
Step 4: Convert extracted audio into suitable numerical forms of data for feature extraction.
Step 5: Extract the following three features,

- Standard deviation of the real part of the FFT signal.
- Mean of the real part of the FFT signal.
- Amplitude of the signal.

Step 6: Store extracted feature vector in a database

5. RESULTS

The tables depicted below represent the percentage split of the dataset and the classifiers used to classify them. SMO classifier in all cases gives the highest accuracy.

Dataset_1: This datasets recordings can be divided into two classes, a class consisting of Good coconuts and a class consisting of Bad coconuts. Here with a split of 60% between the training and testing we get an accuracy of 87.5% using SMO classifier.

Table 1: Classification accuracy obtained for Dataset_1

Classifiers	Percentage Split	
	60%	80%
SMO	87.5	75
Dagging	83.3	75
Naïve Bayes	75	75

Dataset_2: This datasets recordings can be divided into two classes, a class consisting of Good coconuts with good water content and thicker inner meat is and a class consisting of Good coconuts with lesser water and a lesser inner meat. Here in all cases an accuracy of 100% is achieved as the datasets consist of values which can classify the dataset into two proper classes without any overlap. *Feature_1* acted as one of the main features which helped in the classification of this dataset.

Table 2: Classification accuracy obtained for Dataset_2

Classifiers	Percentage Split	
	60%	80%
SMO	100	100
Dagging	100	100
Naïve Bayes	100	100

Dataset_3: This datasets recordings can be divided into two classes, a class consisting of Bad coconuts with no water content and rotten inner meat and a class consisting of Bad coconuts which are cracked. Here results were similar to *Dataset_2*. *Feature_1* acted as one of the main feature which helped in the classification of this dataset.

Table 3: Classification accuracy obtained for Dataset_3

Classifiers	Percentage Split	
	60%	80%
SMO	100	100
Dagging	100	100
Naïve Bayes	100	100

6. CONCLUSION

The proposed methodology uses the concept of audioception to term the usability of a coconut, using the sound produced a coconut can be segregated into the good or bad category. Audacity is used to record the sound made by a coconut colliding into a stationary granite surface. The recordings are then deciphered in Matlab where the status of a coconut is acquired. This concept can be applied in the field of agriculture to convey the property of certain goods.

This concept can mainly be used in large warehouses and godowns. The entire process of coconut grading can be automated by using machines. The accuracy of the proposed method of grading coconuts can further be improved by increasing the number of recordings in the dataset. The number of recordings available in each dataset is currently limited to a few recordings. There can be steps taken to include noise removal algorithms to cancel out unnecessary sounds in the background. A portable and compact version of the entire system can be built. Determining if a coconut can be used for oil extraction is possible. A better enhancement would be if the user approximately knows how many more days the coconut can remain good or usable. Increasing the number of classes into which the coconuts can be classified would make the bifurcation better.

Application of the concept to find out the status of other goods is also possible. For example, by tapping on a watermelon to tell us whether it is ripe or not can also be another application of the proposed concept. Combining the enhancements mentioned with the proposed methodology, a working system to classify coconuts can be built and deployed.

7. ACKNOWLEDGEMENT

We are very thankful to Prof. Joy Paulose, Head of the Department of Computer Science, Christ University, Bengaluru, for his valuable support without which this work wouldn't have been successful.

REFRENCES:

[1] Gong Y. Speech recognition in noisy environments: A survey. Speech Communication. 1995;16(3):261-291.

[2] Campbell J. Speaker recognition: a tutorial. Proceedings of the IEEE. 1997;85(9):1437-1462.

[3] Boll S. Suppression of acoustic noise in speech using spectral subtraction. IEEE Transactions on Acoustics, Speech, and Signal Processing. 1979;27(2):113-120.

[4] Chen ZMaher R. Semi-automatic classification of bird vocalizations using spectral peak tracks. The Journal of the Acoustical Society of America. 2006;120(5):2974-2984.

[5] Fagerlund S. Bird Species Recognition Using Support Vector Machines. EURASIP Journal on Advances in Signal Processing. 2007;2007(1):038637.

[6] Lee C, Han C, Chuang C. Automatic Classification of Bird Species From Their Sounds Using Two-Dimensional Cepstral Coefficients. IEEE Transactions on Audio, Speech, and Language Processing. 2008;16(8):1541-1550.

[7] Somervuo P, Harma A, Fagerlund S. Parametric Representations of Bird Sounds for Automatic Species Recognition. IEEE Transactions on Audio, Speech and Language Processing. 2006;14(6):2252-2263.

[8] Chesmore D. Automated bioacoustic identification of species. Anais da Academia Brasileira de Ciências. 2004;76(2):436-440.

[9] Hermansky HMorgan N. RASTA processing of speech. IEEE Transactions on Speech and Audio Processing. 1994;2(4):578-589.

[10] Jacqueline Libby, Anthony (Tony) Stentz. Using Sound to Classify Vehicle-Terrain Interactions in Outdoor Environments. IEEE International Conference on Robotics & Automation (ICRA 2012), May, 2012.

[11] Lynnworth L. Industrial Applications of Ultrasound - A Review II. Measurements, Tests, and Process Control Using Low-Intensity Ultrasound. IEEE Transactions on Sonics and Ultrasonics. 1975;22(2):71-100.

[12] Bhandari M, Mundi R, Petis S, Kaloty R, Shetty V. Low-intensity pulsed ultrasound: Fracture healing. Indian Journal of Orthopaedics. 2009;43(2):132.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[13] Speed C. Therapeutic ultrasound in soft tissue lesions. Rheumatology. 2001;40(12):1331-1336.

[14] Hossein Peyvandi, Hossein Roufarshbaf, Mehdi Farrokhrooz, Sung-Joon Park. SONAR Systems and Underwater Signal Processing: Classic and Modern Approaches. 1st ed. INTECH Open Access Publisher; 2011.

[15] Stephen Kwasi Adzimah, Samuel Oppong Turkson. Conceptual Design of Coconut Dehusking Machine, Proceedings in Innovative Systems Design and Engineering, 2015;6(5):2222-1727.