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REVIEW ARTICLE

A SYSTEMATIC LITERATURE REVIEW ON SOYBEAN QUALITY ASSESSMENT AND UTILITY OF NEURAL NETWORK IN SEED CLASSIFICATION

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ABSTRACT

Development of a machine vision program to classify among damaged, undamaged, discolored, unmatured, fungi/ diseased soybean kernels can play a vital role in the visual inspection process which is generally performed for grading commercially clean Soybean seed samples. The US standard/ Canadian standard or other recognized standards provide necessary parameters to assess Soybean seeds sample and define its quality while trading Soybean in commercial market. Even today, in many industries, the seed grading process is performed manually and the accuracy of a grade for the given sample is highly de-pendent on human visual inspection. Which most tentatively causes the introduction of errors. To minimize such errors, to shorten the time delay, and increase the accuracy while grading Soybean seeds, an automated system is essentially required. However, till today, very less research work has been carried out on the development of such automated systems for Soybean quality assessment. In that aspect, this paper highlights the key parameters considered as a criteria for assessing quality of Soybean and summarizes the utility of various machine vision techniques in the visual inspection and classification of other type of grains. The selection of parameters and optimization of their values may contribute in improvement of accuracy and shortening of time delay for a designed neural network model.

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INTRODUCTION

Soybean, also known as Golden Bean in America because of comparatively its significant richness in proteins, ability to produce fat free meal at low cost and consumption in the form of oil as well as pulses. The list of top countries in the world producing Soybean at large scale includes United States, Brazil, Argentina followed by China, India subsequently. Soybean originated in China and many other countries started to grow it by the first century AD. Since, past few decades' people started using Soybean and its products extensively and explored a new market for the feed and food industry. A large proportion of the total world production of Soybean, is used for animal consumption and the production of edible oil. Modern Soybean varieties are specially grown for the production of the oil (Tadayoshi Masuda and Peter Goldsmith, 2008; Baohui Song *et al*., 2006). To produce the best quality Soya oil or other secondary products, it becomes essential to use non – defective, non – damaged, clean, perfectly matured Soybean kernels.

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The procurement of such good quality Soybean seeds is one of the major challenges that Soybean products industry is facing in present scenario (https://www.ers.usda.gov/topics/crops/soybeans-oil-crops/policy/, Robert W. Howell, 1975). Conventionally in developing countries, the Soybean kernels purchased by industry are visually inspected by quality experts on sample basis in commercial market and the given lot is graded and passed for further processing. In that situation, it is obvious that the final report submitted by a quality expert based on his/ her visual inspection holds human errors. By relying on such reports and processing further may affect the quality of tertiary product or cause failure in producing desired product. Since a long time this method is being followed in the commercial market and now it is alarming for the need of an automated system for quality assessment of Seeds (Baohui Song *et al*., 2006). Being a fast, adaptive, low cost, object detection and classification technique, the machine vision for seeds inspection can be considered as an able solution. Till date, most of the research work has been carried out by focusing on the areas like seed counting, seed treatment, seed variety identification, detection of seeds quality, but an integrated system comprised of all above units is not being realized for use in commercial market, Science laboratories, industry etc. High portability of such system will be an add-on feature to improve its usability. The execution algorithm of seed analysis integrated system can be based on steps including sample image acquisition that may include multiple images of the same sample, may be captured in different directions so as the error in the input and in turn in the analysis will be minimized, extraction of features, designing of classifier using suitable activation function, optimization of the system while taking care about the issues of overfit and underfit classification. In the proposed integrated system, we also aim to overcome the drawbacks of conventional seed counters, the low processing efficiency, less versatility, problems including imperfect kernel recognition. Finally, we have also mentioned about the most required features in the design (Manouchehri, 2003; Jayme Garcia Arnal Barbedo, 2012).

Soybean Quality

Quality

Certain soybean characteristics and contents are important for end use or processing. The level of these characteristics or contents signifies the quality of Soybean. Such characteristics are many times derived from variation in physical properties and/or chemical compositions of Soybean. Usually high quality Soybeans is desired. Traditionally in the grain marketing system of many countries various standards or conventional ways for measuring the quality of Soybean seeds are being followed, for example the U.S. Grades and Standards, Canadian Grain specifications for commercially clean Soybean. Quality is an important factor for deciding the price of a given lot of Soybean seeds in a commercial market.
Generally, the Soybean seed quality can be tested based on different factors at three different stages like while procuring Soybean as a fresh farm produce, during shipment and storage, and in the aspects related to end consumer before supplying a final tertiary product (Thomas J. Brumm, 2004; Van Eys, 2012).

Defects while procuring Soybean as a fresh farm produce

While procuring Soybean as a fresh farm produce, the factors like damaged kernels, foreign material, splits, kernels of other color, other material mixing are considered as key factors to decide quality of Soybean. The raw Soybean seed sample representing the whole lot brought for commercial sale (i.e. without cleaning) of the weight approximately 1000 – 1050 grams is recommended in FGIS instructions for quality assessment. Usually, a lot carrying soybeans that are infested with live weevils or any other live insects is rejected during the procurement process as it is injurious to stored grains. Presently visual inspection is the widely used method in commercial market for assessing the quality of Soybean during this stage (United States Department of Agriculture, 2016; Thomas J. Brumm, 2004).

- There are basic differences between damaged kernels and heat damaged kernels. Heat damaged kernels are materially discolored essentially due to drying of grain and give off an odor like smoke. Sometimes due to excessive drying kernels outer layer cracks or shrinks. Other types of damages also cause discoloration of kernels but in different ways. Frost Immature Green damage can be observed when due to any cause Soybean kernel remains immature and green colored. Sprout damage is confirmed only if it can be distinctly seen. Kernels containing Insects, Insect Webbing, and Insect Refuse are counted as Insect damaged kernels (United States Department of Agriculture, 2016; Thomas J. Brumm, 2004).
- As per the guidelines provided by FGIS, Foreign material is a matter that does not pass through an 8/64 round-hole sieve. One can include sticks, other seeds, handpick materials in the list of foreign material.
- Soybean kernels with approximately more than 25 % of the whole size removed as well as which can’s be categorized as damaged, not shrink are defined as Split. Splits can’t be effectively separated from sample by sieving. Hence, one needs to examine sample portion that remains on the top on the sieve and the material that passes the sieve (usually of dimensions 8/64 x 3/4 oblong hole) (United States Department of Agriculture, 2016; Van Eys, 2012).
- When a Soybean sample (other than mixed soybeans) is supposed to have all the kernels in one color i.e. yellow, the Soybean kernels of other colors like black, green, brown, bicolored present in the sample affect the grading factor. Soybean hilum does not act as a component while counting Soybeans of other colors.
- The maximum count of other materials such as animal filth, glass, stones, and unrecognized foreign substances mixed/ present in Soybean sample is limited in Grades U. S. Nos.
- Odor is also one of the basis factors in the inspection procedure of soybean lot. Odor of a Soybean lot can be determined at the time of sampling or on the sample either before or after the removal of foreign material (Thomas J. Brumm, 2004; Jaya Joshi *et al*., 2014).

Table 1. Official U.S. Grades for Soybeans (FGIS, 1994)

Grading Factors	Grades U. S. Nos.			
	1	2	3	4
	Maximum percent limits of			
Damaged Kernels:				
Heat (part of total)	0.2	0.5	1.0	3.0
Total	2.0	3.0	5.0	8.0
Foreign material	1.0	2.0	3.0	5.0
Splits	10.0	20.0	30.0	40.0
Soybeans of other colors1/	1.0	2.0	5.0	10.0
	Maximum count limits of			
Other Materials:				
Animal filth	9	9	9	9
Castor beans	1	1	1	1
Crotalaria seeds	2	2	2	2
Glass	0	0	0	0
Stones2/	3	3	3	3
Unknown Foreign Substance	3	3	3	3
Total3/	10	10	10	10

U.S. sample grade are soybeans that:
(a) Do not meet the requirements for U.S. Nos. 1, 2, 3, or 4; or
(b) Have a musty, sour or commercially objectionable foreign odor (except garlic odor); or
(c) Are heating or otherwise of distinctly low quality.

1/ Disregard for Mixed soybeans.
2/ In addition to the maximum count limit, stones must exceed 0.1 percent of the sample weight.
3/ Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones and unknown foreign substances. The weight of stones is not applicable for total other material.

Factors caused by storage or shipment

Usually, the grains with outer coating cracked or infested have high tendency to quickly get defected during storage or shipment. Variation in moisture contents of Soybean kernels is one of the important factors affecting its quality during this stage. The moisture content is comparatively small but greatly affects the quality of Soybean oil. The mold growth of a Soybean kernel is also dependent on its moisture contents. Mold growth is always undesired when one desires to preserve or process Soybean in order to obtain a tertiary product, as during mold growth the internal temperature of soybeans increases significantly which subsequently may result in auto-combustion causing an irreversible harm to the product quality. Hence it becomes necessary to monitor the continuously monitor and maintain the moisture content in Soybean. Moisture content in grains can be determined by one of the following methods, using air oven, chemical, gravimetric (Purcell, Larry, 2014) (Purcell, Larry, 2000). In U. S., majorly the moisture content is measured by a simple method including the drying of Soybean sample in constant 1300C for 30 minutes in an oven and repeatedly following the same till the weight loss is less than 0.05% per 30 minutes then after 3 hours the moisture content can be measured as;

$$Moisture\ \% = \frac{Loss\ in\ sample\ weight}{Weight\ of\ the\ sample} * 100 \qquad (1)$$

It is also required to protect grains from insect infestation while shipping or storing it before processing into a final product. The grains infested with insects, borers, weevils can't be used for product manufacturing as it degrades the quality of final product, also reduces the product's natural storability and in rarest cases may turn product into non edible food. On the other hand, it is a commercial loss for the grain procuring party as well. By storing Soybean grains in appropriate conditions can help in avoiding degradation of grain quality (United States Department of Agriculture, 2016; Van Eys, 2012).

Quality Factors in the aspect of End user

Soybeans may be counted as one of the major sources in food which can provide essential nutrients. Ideally, from a 100-gram sample of perfectly matured Soybean seeds, we get 9% water, 30% carbohydrates, 20% fats and 36% protein (Nutrient data laboratory, 2016). In this category, generally the quality of Soybean is defined in relation to the needs of user. Different users may have different needs. Hence, it solely depends on the process they wish to implement and the final produce desired from that process. Along with physical properties of Soybean, few chemical properties which are commonly considered to test the quality of final product can be listed as; Composition of Proteins, Oil and Sugar, Nitrogen Solubility index, Protein Dispersibility index Ratio of 7S/ 11S proteins etc.

The ASH content of Soybean products can be determined by taking 2 grams of sample and placing it in a furnace at 6000C for 2 hours. The ASH content is measured as;

$$ASH\ \% = \frac{Final\ weight}{Initial\ Weight} * 100 \qquad (2)$$

In Soybean products the protein content is estimated as 6.25 times the total nitrogen in the sample. Hence, it is referred to as crude protein. The nitrogen present in non-protein format is comparatively negligible. Hence, basic principle mentioned just before can be used for the measurement of protein content. Two methods are widely known to perform the nitrogen measurement; First method designed by Dumas is based on the combustion of nitrogen and the second method designed by Kjeldahl is centered on the reaction between sulfuric acid and organic matter. Urease Index, KOH protein solubility, Protein Dispersibility Index, Protein quality ruminants are helpful to indicate the protein quality (United States Department of Agriculture , 2016; United States Department of Agriculture , 2016; Dr. Erhard Briendenhann, 2013). Lipoxygenases is a type of enzymes that creates off-flavors in soybean products. Trypsin is another type of enzyme that degrades and digests protein. Modern verities of Soybean may not contain these enzymes. Oil is a fraction of Soybean which can be extracted mechanically by squeezing Soybean kernels. Soybean oil is composed of 3 fatty acids classified based on the number of carbon atoms and the number of double bonds between these atoms. Likewise, fatty acids can be categorized as saturated (no double bond), Mono – unsaturated (only one double bond) and Poly – unsaturated (Multiple double bonds). Modern Soybean varieties produce saturated fatty acids in lesser quantity. Gas or liquid chromatography can be used for determining the fatty acid outline for a given Soybean sample (Jaya Joshi *et al*., 2014; Nutrient data laboratory, 2016). Coating of a Soybean seed majorly contributes in another class of its constituent components that is crude fiber. Crude fiber is mainly responsible for comprising structural carbohydrates. Laboratory setup is widely used for the testing of Fiber, oil fatty acids, starch, soluble sugar and enzymes (Van Eys, 2012). One of the constituent elements of nonstructural carbohydrates is soluble sugar and it greatly contributes in deciding the taste of Soybean food as well as its fermentation ability. Generally, it is found in range of 6 to 17 percent and can be tested in laboratory (Thomas J. Brumm, 2004; Van Eys, 2012; Purcell, Larry, 2016). Few other chemical components like flavonoids are also present in soybean in small percentages and may be useful in food processing industry up to certain extent.

Computer vision for visual inspection of soybean and other grains

As per the grading standards for Soybean, followed worldwide, in commercial market, the visual inspection of Soybean sample is a basic method for assessing its quality. Till date many researchers have carried out their research work in order to automate the process of Soybean quality assessment with the help of computational models and techniques such as image processing techniques incorporating morphological operations, object detection and classification techniques, using machine learning concepts, artificial neural networks. A survey on few of such techniques is being performed and presented in this section (Van Eys, 2012; Jaya Joshi *et al*., 2014; Manouchehri, 2003).

Steps Followed in Image Classification

The correctness in deciding the quality of Soybean is mainly dependent on the accuracy in classification of Soybean grains based on their features respectively. Conventionally, in image processing the classification can be object based or pixel based. In last few decades people have started using neural networks, decision tree and machine learning to make the process fast, adaptive and more accurate. Broadly, the steps commonly followed by classifier algorithms in image processing and computer vision techniques can be listed as:

Defining the Classification approach and different classes: Clarity on objectives of classification and data/ information characteristics help in formulating the classification approach as well as stating different classes.

Features Selection and Extraction: The features which can significantly discriminate between classes shall be wisely selected and the method for extracting those features shall be specified. Normally, shape features, spectral features, texture features, transform features are considered as important features in image processing. However, it is assumed that the morphological features can effectively discriminate as compared to color and texture. Hence, morphology along with color features produce better results.

Feature Reduction/ Sampling of Training Data (if required): If in case some redundant components are present in the features set obtained from step 2 then appropriately it must be sampled to enable the selection of classification technique. Usually, after transforming an input data some redundant features are discarded which also helps in reducing the needs for processing a large training data.

Estimation of universe statistics: The main decision while classifying elements, may be at pixels or objects, is always taken on the basis of certain rules. So, it becomes essential to state the decision rule most suitably and in a systematic manner. Sometimes, in order to bring advantages the combination of multiple decision rules is also being recommended.

Classification: In this step the actual classification of pixels or objects present in an image takes place. Many classic supervised classifiers like Minimum distance, Parallelepiped, Maximum likelihood etc., Unsupervised classifiers like K – means clustering, other Non-parametric classifiers like Decision trees, Artificial Neural Networks, Support Vector Machine, Nearest neighbor etc., Hard classifiers using crisp, Soft classifier using Fuzzy have been designed by the researchers so far.

Result Verification/ Assessment: Assessment of the results of classification on the basis of parameters like accuracy, reliability, response time is always recommended (Mário Caetano, 2009; David, 2015).

So far, the research work on purity testing as well as quality assessment of grains or seeds has been widely focused on Rice, Weed, Corn, Oats, Wheat, Rubber, Cotton, Barley, however it is limited in case of Soybean seeds. As the authors of this paper aim to conduct a literature review on application of computer vision techniques for Soybean seed quality assessment, the review on references related to the same is being mentioned in following section. S. Gunasekaran *et al*., 1988, published their work on Soybean seed coat and cotyledon crack detection by Image Processing (Gunasekaran *et al*., 1988). They developed a computer vision system to evaluate seed coat and cotyledon cracks in soybeans. Seed sample was placed on a black background and exposed to White light from front side. Being a system in primary stage of its development had many limitations, as it was required to position soybean seeds so that the crack can be viewed directly by the camera of the vision system and then the software based algorithms could process that image. Their designed system under certain constraints could successfully test given samples with accuracy greater than 95.9 %. Irfan S. Ahmad *et al*., 1999, proposed a color classifier for symptomatic Soybean seeds using image processing (Irfan S. Ahmad *et al*., 1999). Fungal damage, immaturity, viral diseases in Soybean seeds were characterized in an image processing algorithm. Multivariate decision rule based color features played a vital role in discriminating symptomatic seeds from other seeds for visual inspection. This model comprised six color features which were found to be insufficient in adequately distinguishing among some of the symptoms. Due to that overall accuracy in successful classification is restricted to 88%. T.F. Burks *et al*., 2005, evaluated three different Neural network classifiers for Weed Species Discrimination by using Color Co-occurrence Method texture analysis techniques and after comparative study of three neural networks including back propagation, radial basis function, counter-propagation could conclude that the Back Propagation Neural network performs classification with 96.7% accuracy (Burks *et al*., 2005). HAN Zhong-zhi *et al*., 2010, performed a quality grade testing of Peanut using image processing (Han Zhong-zhi *et al*., 2010). For this purpose, they employed a back propagation neural network taking input features like shape, texture, color. The sample of 1400 grains including unsound kernels, impurities, other grains is considered for training and there after the testing resulted in successful classification with 95.6% accuracy.

Min zhao *et al*., 2011, attempted to combine Genetic Algorithm and SVM for corn variety identification on the basis of features like color, texture, shape and could claim the accuracy up to 94.4% with a processing time of 0,141 s for each seed on an average for their proposed algorithm (Min zhao *et al*., 2011). For training purpose 20 images were taken and for testing purpose 30 images were taken. Kuo-Yi Huang, 2012, worked on detection and classification of areca nuts with Machine Vision (Kuo-Yi Huang, 2012). Kuo-Yi Huang tried to qualitatively classify areca nuts by using a back propagation neural network having input layer with 10 nodes fetching SR area, geometric features and color features. The areca nuts were classified as Excellent or Good or Bad in the output layer. Kuo-Yi Huang conducted an experiment on 144 areca nuts in which 49 were Excellent, 46 were Good, and 49 were Bad. 287 images obtained from random sampling of these nuts were used for training and could successfully classify testing sample with minimum accuracy of 89.1%. Alireza Pourreza *et al*., 2012, modelled a linear discriminant analysis classifier for identification and classification of nine Iranian Wheat seed varieties on the basis of features like textural and performed classification with accuracy between 88.33% - 100% (Alireza Pourreza *et al*., 2012).

Si Chen *et al*. 2012, designed a classification model of seed cotton grade based on least square support vector machine regression method (Si Chen *et al*., 2012). The features like color, brightness, hue, characteristics of impurities input were taken as an input to traditional method of neural network, after training the network, testing of classification produced results with 83% accuracy. Authors also mention that it is difficult to improve the accuracy with tradition method of neural network classification. Hence, the least square principle by using the support vector machine is being implemented to enhance accuracy of results. Vinita Shah *et al*., 2013, presented a solution for quality assessment and grading of an important cereal grain that is rice (Vinita Shah *et al*., 2013). Krishna Kamod rice is evaluated using a nondestructive technique incorporating morphological features in image processing like major axis length, minor axis length, area, eccentricity for counting the number of rice kernels and a trained multi-layer feed forward neural network for classification. Authors observed an improved accuracy in machine vision system operation as compared to human visual inspection. Anindya Ghosh *et al*., 2014, proposed probabilistic neural network system for cotton yam defects classification. neps is one of the major defects causing significant damage to textile products (Anindya Ghosh *et al*., 2014). The proposed neural network aims to classify coat neps and fibrous neps. After training and testing, the probabilistic neural network is claimed as robust, fast, accurate and simple classifier. The fivefold cross validation is referred as performance measure for proposed system which can achieve 96%-99% accuracy while testing input data. Anita Kinnikar *et al*., 2015 conducted a survey on detection and identification of seed borne diseases of soybean using image processing and proposed an approach including major tasks as defect segmentation by using K – means clustering, feature extraction, training and classification (Anita Kinnikar *et al*., 2015). Later on they trained a support vector machine for detection of diseases.

Surbhi Sood *et al*., 2016, published their work on internal crack detection in kidney bean seeds using X-ray imaging technique (29). Authors recommended that in order to accurately assess the quality of seeds, internal and external both the morphological characteristics should be taken into consideration. With the help of soft X-ray imaging technique, it is possible to visualize the internal morphological characteristics like internal cracks of Kidney beans in a non-destructive manner. For the analysis purpose, the X-ray images of the sample were taken as an input then histogram thresholding followed by morphological operations, image segmentation and feature extraction were performed. Extracted features enabled machine to detect internal cracks automatically. From obtained results the usability of X-ray imaging techniques can be justified.

Conclusion

In this paper, the quality assessment of Soybean is ordered in to 3 stages based on the parameters to be tested i.e. while procuring Soybean as a fresh farm produce, while storing or shipping, and in the aspect of end user which mainly includes the testing of chemical composition. It is also being highlighted that while trading Soybean in a commercial market, the quality assessment mainly depends on the human visual inspection which causes inclusion of errors in the process and also alarms the need of an automated system. In the systematic literature review conducted, it is found that, till date very less work has been done on the development of a machine vision system for the quality assessment of Soybean. The review of quality assessment techniques for other type of grains like Wheat, Rice, and Cotton etc. emphasizes on the utility of a neural network to perform the task. Also any particular criteria for specifying the number of neurons to be considered, number of layers to be included while designing a neural network as well as the justification on cascading of a particular processing technique are not stated. The selection of parameters and optimization of values of those parameters may contribute in improvement of accuracy and shortening of time delay for a designed neural network model.

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