# Classification of Food Powders with Open Set using Portable VIS-NIR Spectrometer


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***Abstract*— Near Infrared (NIR) spectroscopy is fast and non-destructive methods for analyzing materials without pre-treatment. Especially as portable NIR spectrometers have been developed, the research of spectral analysis has applied to various open environment and field. In this paper, we classify visually indistinguishable eight food powders using portable VIS-NIR spectrometer with a wavelength range of 450 to 1000 nm with CNN (Convolutional Neural Network), one of the machine learnings. Further we consider open set recognition where unknown classes should be rejected at test time. The proposed CNN model achieved an accuracy of 100% for eight food powders, and 91.2% with open set. Our experimental results demonstrate the potential of material analysis using a portable VIS-NIR spectrometer with machine learning.**



***Keywords*— *near infrared spectroscopy; portable VIS-NIR spectrometer; food powder; open set; machine learning***


## I. Introduction

NIR spectroscopy is useful tool to analyze materials as is fast and non-destructive methods and requires no pretreatment. Consequently, NIR spectroscopy is applied various field as material analysis methods. For instance, It's applied in agricultural applications to measure the moisture in grain and is used identification of genetically modified organisms (GMO) foods. Especially machine learning has been combined, NIR spectroscopy application areas are expanding [1-3].

General industrial or laboratory NIR spectrometers have excellent performance. However, these industrial or laboratory NIR spectrometers have been limited to controlled laboratory environments. They are generally expensive and bulky, which is not suitable for use in various locations. Therefore portable NIR spectrometers are being developed and verified. The portable VIS-NIR spectrometers are inexpensive compared with conventional industrial or laboratory NIR spectrometers and can be used in various locations [4-6].

In this paper, we classify eight food powders using portable VIS-NIR spectrometer with machine learning. Our classification result demonstrate the potential for analyzing food ingredients using a portable VIS-NIR spectrometer. In addition, we classify open set which is four colors into unknown class. Open set is important issue in machine learning. In this experiment, we solve open set using Openmax which is applied meta-recognition system with CNN [7-9]. As openmax successfully classify open set, we show the advantage of applying NIR-VIS spectrometer with machine learning to real various field.

## II. Materials and Methods

### A. Portable VIS-NIR spectrometer

In this paper, we use a portable VIS-NIR spectrometer from Stratio, Inc. (www.stratiotechnology.com) called LinkSquare™. The LinkSquare™ is a Silicon (Si)-based VIS-NIR spectrometer that is significantly more affordable than the NIR spectrometers typically found in the industrial or laboratory. This VIS-NIR spectrometer has two light sources (White LED and BULB), and measures wavelength the range of 450 to 1000nm. Stratio also provides the Software Development Kit (SDK), Android and iOS App for users to collect their own data and to develop. Table ˜ and Fig. 1 show the detailed specifications and appearance of LinkSquare™ [10].

TABLE I. Specifications of LinkSqure™.

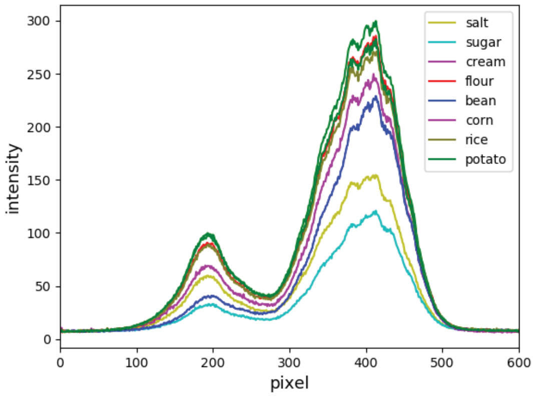
| LinkSquare™ | |
|---|---|
| **Company** | Stratio, Inc. |
| **Measure Range** | 450 – 1000nm |
| **Size** | 114 x 23.9 x 23.9 mm /4.5x 9x 9 in |
| **Weight** | 57g/2oz |
| **Battery (active)** | ~1000 scans |
| **Battery (idle)** | > 24 hours |

Fig. 1. LinkSquare™.

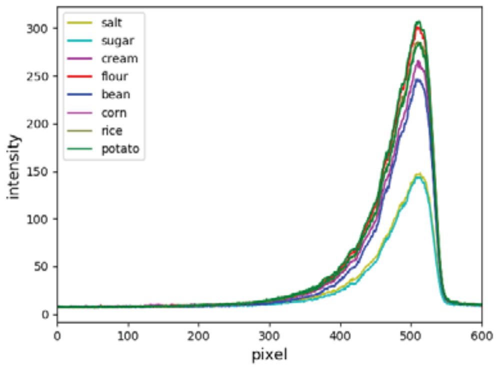
### B. Food Powders

We measure eight common food powders that are visually indistinguishable: salt, sugar, cream, flour, bean, corn, rice, and potato powder using VIS-NIR spectrometer. Fig. 2 and Fig. 3 show eight food powders and their spectral data respectively.


Fig. 2. Eight food powders.




(a) Spectral data of LED




(b) Spectral data of BULB

Fig. 3. VIS-NIR spectral data.

## III. Classification System

### A. Machine Learning

In this paper, we use CNN(Convolutional Neural Network) for classification system. CNN algorithm is one of deep learning which is useful tool for image classification. We design CNN model which is similar AlexNet that is 2012 ImageNet victorious model [11]. Fig. 4 shows the procedure of the designed CNN model. We separate two CNN model for spectral data of LED and BULB. It's combined on first fully connected layer.

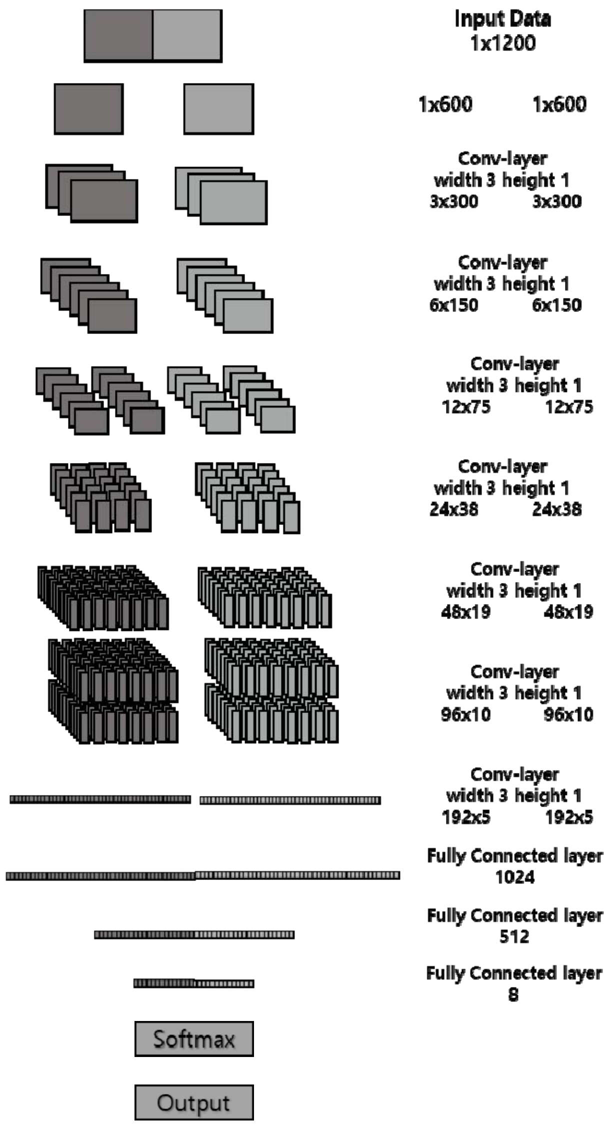



Fig. 4. The architecture of the CNN model.

### B. Experiment

We measured each eight food powders 100 time using LinkSquare$^{TM}$. We then divide the total sample set (800 samples) into a training sample set (640 samples) and a validation sample set (160 samples). We then train the designed CNN model with the training set. We demonstrate the performance of CNN model with the validation sample set.

### C. Result

We verify the CNN model using validation sample set. The validation results are shown in Table ˜ . The proposed CNN model achieve 100% correct classification result. Next, we investigate the impact of the number of iteration for efficient machine learning training. Fig. 5 shows the impact of the number of iteration on the classification performance. The CNN model show near accuracy of 100% in low number of iteration.

TABLE II. THE SCORE OF THE PROPOSED CLASSIFICATION MODEL.

| Accuracy | Precision | Recall | F1-score |
|---|---|---|---|
| 100% | 100% | 100% | 100% |

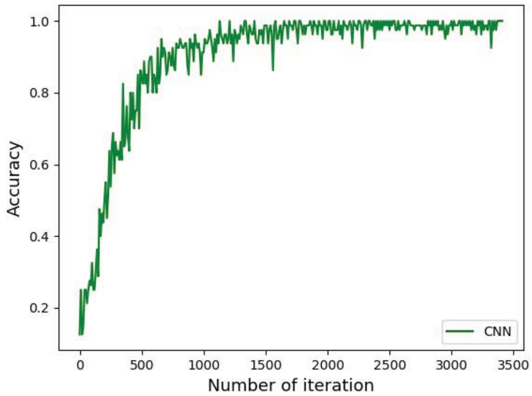



Fig. 5. Impact of number of iteration.

## IV. OPEN SET

### A. Limitaion of proposed system

We successfully classified eight food powders using CNN model. However, this is because we assumed all categories are known a priori. We consider open set, i.e. the classification system should reject unknown (during training) classes at test time. This is important issue on machine learning.

### B. Openmax

In this paper, we use Openmax approach to recognize open set. Openmax approach was proposed for predicting an unknown class by extending Softmax [7]. The Openmax is used to estimate the probability for a given input belonging to an unknown class. For this estimation, Openmax adapts the concept of Meta-Recognition to deep neural networks [8]. Openmax uses the scores from the output of the fully connected layer of deep networks to estimate if the input is "far" from known training data.

### C. Experiment & Result

In this paper, we measured each four colors (Sky, Yellow, Sage, White) 100 time, which are used as open set. The proposed experiment procedure with open set is shown in Fig. 6. Four colors are not used for training. Only training sample set (640 samples) is trained for CNN model.

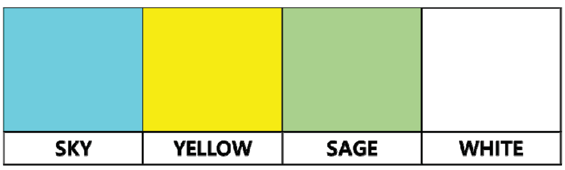



Fig. 6. Four colors.

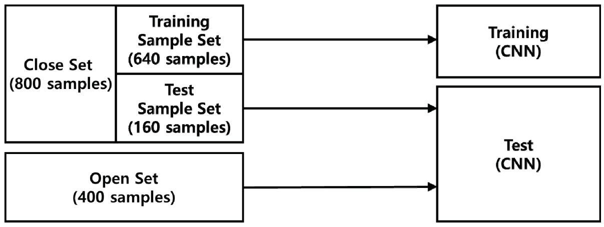



Fig. 7. Training and validation process.

To compare the performance of Openmax, we modified the Softmax layer by setting the threshold. It classifies as an unknown class when output of Softmax layer less than threshold. The validation results are shown in Fig. 8 using validation sample set (160 samples) and open set (400 samples). Table ˜ shows validation result with open set. The Openmax achieve high accuracy of 91% and show successfully classification to an unknown class.

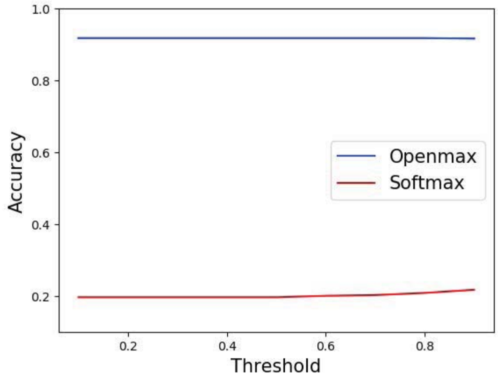



Fig. 8. Accuracy of softmax and openmax with validation sample set and open set.

| Threshold | Softmax(%) | Openmax(%) |
|---|---|---|
| 0.1 | 0 | 91.2 |
| 0.2 | 0 | 91.2 |
| 0.3 | 0 | 91.2 |
| 0.4 | 0 | 91.2 |
| 0.5 | 0 | 91.2 |
| 0.6 | 0.05 | 91.2 |
| 0.7 | 0.07 | 91.2 |
| 0.8 | 0.15 | 91.2 |
| 0.9 | 2.75 | 91.2 |

TABLE III. ACCURACY OF SOFTMAX AND OPENMAX WITH OPEN SET.

## V. CONCLUSION

We show successful classification results for eight food powders using portable VIS-NIR spectrometer. In addition, we classified four colors into unknown class using Openmax when CNN model only trained eight food powders. These results show excellent performance of portable VIS-NIR spectrometer and potential for combination of machine learning. As portable VIS-NIR devices develop further, they can be used for more varied purposes.


## ACKNOWLEDGMENT

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