# Nighttime Sea-fog Detection from Geostationary Satellite using Machine Learning

Dae Sung Choi, Jae Hwan Kim, Seyun Min
Pusan National University
daesungchoi@pusan.ac.kr

## 1. Introduction

- Machine Learning is the most advanced techniques applied to various fields.
- We tried to apply Machine Learning algorithms to Sea-fog Detection from the geostationary satellite monitoring the asia and the pacific region, COMS (Communication, Ocean and Meteorological Satellite).

- Traditional sea-fog detection algorithm from geostationary satellite is Brightness Temperature Difference Method(BTD method). This method is based on optical properties of warm fog near the sea surface. However, the BTD method is not appropriate to distinguish sea fogs and low clouds. Due to due limitations of the channels, occlusion of higher clouds, and difficulties for numerical predictions, fog is one of challenging subjects to predict, detect, monitoring.

- In this research, we studied for effects of Machine Learning algorithms, find a way for make improvements to detect fog for a wide range from geostationary satellite.

## 2. Data

- The data used in this research are shown below.
  - The COMS geostationary satellite for monitoring Asian Pacific region
    - IR1(10.8 μm), IR3(6.7 μm), IR4(3.7 μm), the differences for each IR3-IR1, IR4-IR1, IR4-IR3
  - Cloud Vertical Feature Mask Profile from Polar orbit satellite CALIPSO Lidar
  - GHRSST Level 4 OSTIA Global Foundation Sea Surface Temperature
  - 2011~2014 May-July, the most frequently sea-fog generated season
  - The true fog pixels defined from CALIPSO Vertical Feature Map data(Wu et al., 201)

## 3. Methods

- Decision Tree(depth test for 2~19)
- Logistic Regression
- Multi-Layer Perceptron
- Convolutional Neural Network
- Maximum Entropy Method
- BTD&STD Method - Traditional Brightness Temperature Difference Methods with Sea Surface Temperature Difference Method to the comparison. (Shin et al., 2013)
- Tools:
  - Sci-Kit Learn(Pedregosa *et al., 2011)*
  - Tensorflow(Adabi et al., 2016)

- 3.1.1. Decision Tree
  - Decision Tree algorithm is basic machine learning algorithms to classify the target with Tree structures with simple conditions. In this research, CART algorithm is used for classifier.

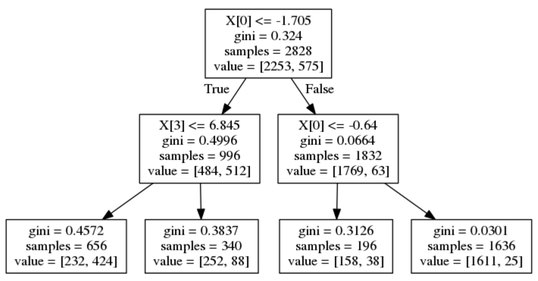



Fig. 1. Decision Tree structure of satellite fog detection for depth = 2.

- 3.1.2. Logistic Regression
  - Logistic Regression is simple regression method using logistic function as a classifier. The logistic function is shown below.
  - $\widehat{Y}_i = \frac{e^u}{1+e^u}$
  - $u = A + B_1X_1 + B_2X_2 + \ \ldots + B_KX_K$

- 3.1.3. Multilayer Perceptron
  - The Multilayer Perceptron is one of artificial neural networks with multi layers. In this research, layers are constructed with width of 9, 8, 7, 6, 5.

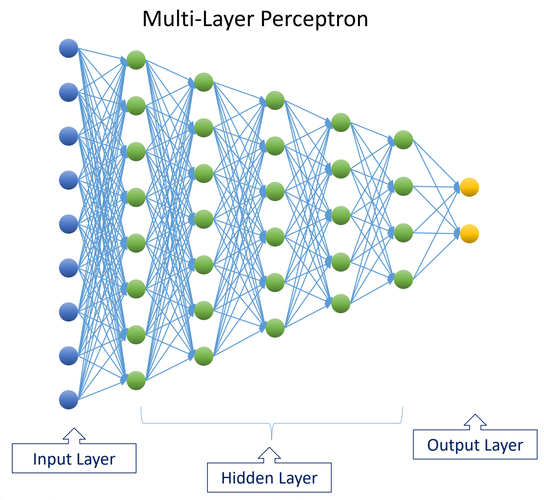



Fig. 2. Multilayer perceptron structure of 5 hidden layers.

- 3.1.4 Convolutional Neural Networks without spatial features are used for detect fog just as a numerical technique. The general usage of CNNs is for detect spatial features or image recognition. However, in this research, we did not implement the spatial features of a satellite image. The spatial feature will be our next subject to detect fog.
- 6 Hidden layers of 16, 32, 64, 128, 256, 512 are used. The max pooling is applied to the second and fourth layers.

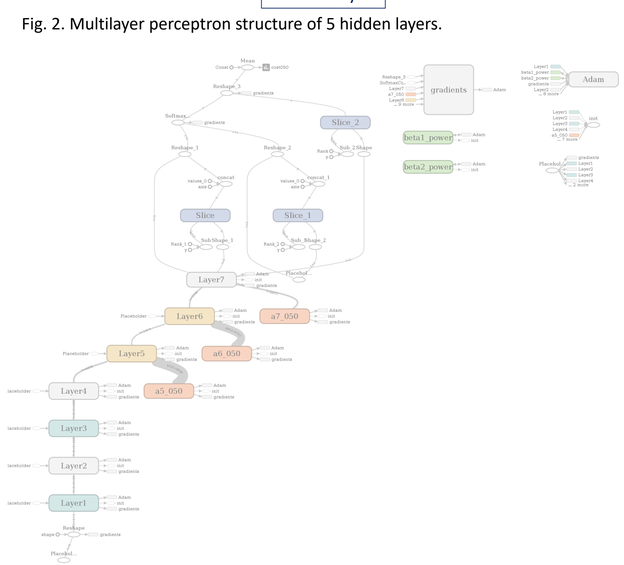



Fig. 3. Convolutional Neural Networks Structure from Tensorboard

- 3.1.5. Maximum entropy method
  - The Maximum Entropy Methods, originated from the information theory, are used in the fields of the Species Distribution Models which consider the environment variables without observation of training data as a pseudo-absence data for the training. . (Phillips et al., 2006)

$$H = -\sum_i \mathrm{p_i} \ln p_i$$

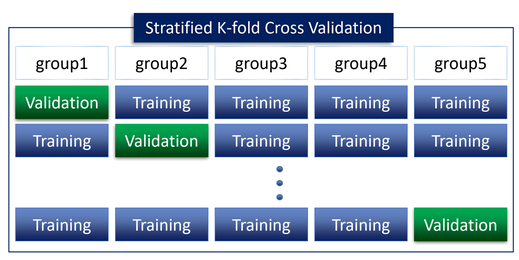
  - Maximizing entropy is identical to Maximizing Penelized Likelihood Function(Phillips and Dudik, 2008).

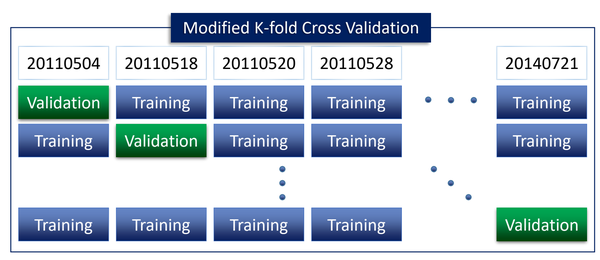
$$q_\lambda = \frac{\exp(\sum_{j=1}^{n} \lambda_j f_j(x))}{z_\lambda}, \qquad \frac{1}{m}\sum_{i=1}^{m} \ln(q_\lambda(x_i)) - \sum_{j=1}^{n} \beta_j |\lambda_j|$$

    - Second term is Lasso penalty and error of environment variable $\beta_j$

- 3.1.6 BTD & STD method
  - For the comparison, the climatological threshold for BTD and STD is calculated and applied to detect sea fog.

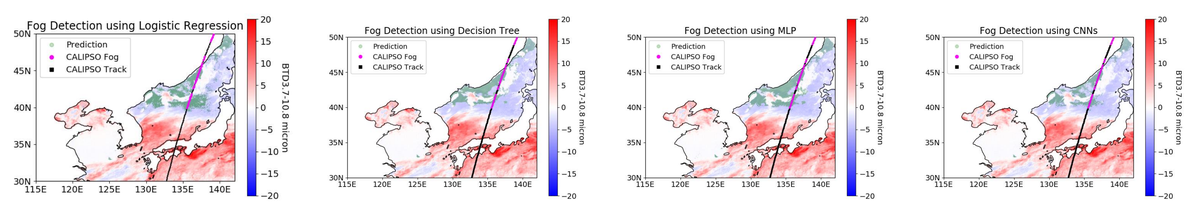
- 3.2 Validation method
  - Stratified K-fold Cross-Validation (K-fold CV)
  - Modified K-fold Cross-Validation that split for each day(Day-fold CV)




## 4. Results

- The Examples of the sea-fog detection result for 2011-05-04 is presented.




- The comparison of the results of each Machine Learning method for sea-fog detection is shown below. Modified K-fold Cross-Validation and Day-fold Cross-Validation methods are applied. Monthly results for K-fold CV for May.

| | Day-fold | | | | K-fold | | | |
|---|---|---|---|---|---|---|---|---|
| | Accuracy | POD | FAR | CSI | Accuracy | POD | FAR | CSI |
| Decision Tree(Depth=2) | 0.7930 | 0.7445 | 0.4931 | 0.4317 | 0.8553 | 0.7218 | 0.3700 | 0.5069 |
| Logistic Regression | 0.8198 | 0.5286 | 0.4323 | 0.3769 | 0.8337 | 0.5499 | 0.3935 | 0.4053 |
| Multi-Layer Perceptron | 0.8235 | 0.6383 | 0.4364 | 0.4272 | 0.8489 | 0.5270 | 0.3306 | 0.4182 |
| CNNs | 0.8070 | 0.5237 | 0.4676 | 0.3587 | 0.8684 | 0.6629 | 0.3275 | 0.5011 |
| Maximum Entropy | - | - | - | - | 0.9026* | 0.3122* | 0.5204* | 0.2332* |
| BTD&STD** | 0.8482 | 0.7610 | 0.3953 | 0.5082 | 0.8482 | 0.7610 | 0.3953 | 0.5082 |
| COMS_FOG** | 0.9303 | 0.3832 | 0.5111 | 0.2736 | 0.9303 | 0.3832 | 0.5111 | 0.2736 |

*Result of Maximum Entropy is for not monthly but whole period.
**BTD&STD and COMS_FOG are the method for the comparison. These methods are same for Day-fold and K-fold.

## 5. Discussion

- The Accuracy is the score applied the whole confusion matrix(True Positive, False Positive, True Negative, and False Negative). However, The Higher POD and CSI and lower FAR could be more critical than the Accuracy for early-warning to sea fog.
- From the result of Fog detection based on Machine learning algorithms of geostationary satellite COMS MI sensor and OSTIA SST data, nevertheless the small differences among the methods, generally the performances of the machine learning algorithms are higher than COMS_FOG and close to BTD&STD.
- It seems that Machine Learning algorithms are still underfitted and possible to fit more(avoiding overfitting)
- The COMS_FOG represent the highest score for accuracy, but the POD is under 0.4 and FAR is over 0.5.The K-fold CV is the method to split samples as K groups. There is a tendency that K-fold was showing better results than Day-fold. One of the possible reason for that is the daily characteristics of satellite data is included for training and test samples both.

## 6. Reference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