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Applying Soft Computing for Remote Sensing Data Composite Algorithms

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Abstract: Remote sensing of the earth surface using satellite mounted sensor data is one of the most important methods for global environmental monitoring today. However, when using satellite sensor data, clouds in the atmosphere can interfere with the remote sensing, and specific land points may not be correctly monitored on a given day. In order to overcome this problem, a common workaround is to use multiple day composite data. Multiple day composite data uses several consecutive days' remote sensing data, and picks the most accurate data within the temporal dataset for the same land point. This allows creating a more complete dataset by patching together data uninterfered with clouds during a specified time period, to create a clearer, more usable dataset. In this paper, we propose applying soft computing, namely fuzzy logic, in order to select the clearest data in the temporal interval for the composite data. Moderate resolution remote sensing data of areas in Japan were used for evaluation, and results were compared with previous composite methods.

Keywords: remote sensing, composite algorithm, MODIS, fuzzy logic

I. INTRODUCTION

Remote sensing of the earth surface using satellite mounted sensor data is one of the most important methods for global environmental monitoring today. For example, changes in land surface use can be monitored using remote sensing data. By monitoring the changes of vegetation coverage, the amount of carbon held in vegetation and how much is released into the atmosphere can be calculated.

However, when using satellite sensor data, clouds in the atmosphere can interfere with the remote sensing, and specific land points may not be correctly monitored on a given day (Fig.1). In order to overcome this problem, a common workaround is to use multiple day composite data. Multiple day composite data uses several consecutive days' remote sensing data, and picks the most accurate data within the temporal dataset for the same land point (Fig.2). This allows creating a more complete dataset by patching together data uninterfered with clouds during a specified time period, to create a clearer, more usable dataset.

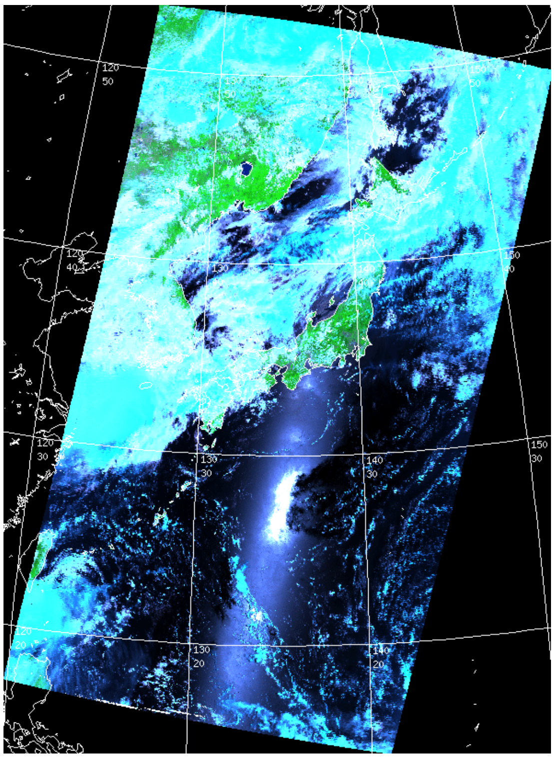

Fig.1. 1 pass of MODIS data with cloud interference

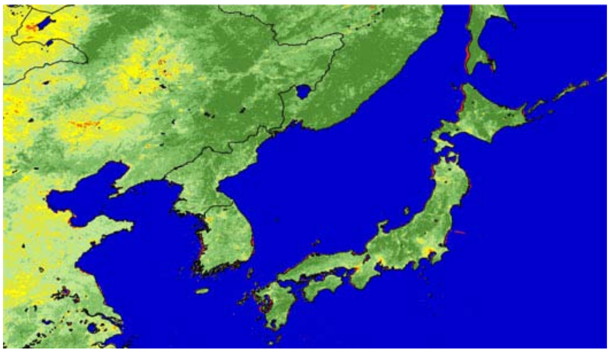

Fig.2. Monthly composite data

There have been many data composite algorithms proposed, and different methods have their merits and demerits, but all methods require tuning of parameters to achieve best accuracy for a specific region. In this paper, we propose applying a soft computing approach, namely fuzzy logic[3], in order to facilitate tuning of the data composite algorithm in order to achieve the best accuracy for a specific region. Moderate resolution remote sensing data of areas in Japan were used for evaluation, and results were compared with previous composite methods.

II. SATELLITE DATA

With the increased interest in monitoring the global ecological changes, the demand for satellite remote sensing has increased. NASA-centered international Earth Observing System project has launched many satellites to monitor the earth for scientific purposes, including Terra and Aqua.

A key instrument aboard the Terra and Aqua satellites is MODIS (Moderate Resolution Imaging Spectroradiometer). Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS enable the viewing of the entire Earth's surface every 1 to 2 days. MODIS captures data in 36 spectral bands, or groups of wavelengths. Moderate resolution remote sensing allows the quantifying of land surface type and extent, which can be used to monitor changes in land cover and land use for extended periods of time. This data is used to monitor and understand global dynamics and processes occurring on the land, oceans, and lower atmosphere.

For this paper, we used MODIS data collected at Tokyo University of Information Sciences (TUIS), Japan. TUIS receives satellite MODIS data over eastern Asia, and provides this data for open research use.

III. COMPOSITE ALGORITHM

There have been many different satellite data composite algorithms proposed [1][2], and each method have different merits depending on the target usage. Different composite methods include 1) MVC (maximum value composition) using maximum NDVI (normalized difference vegetation index), 2) MVC using maximum temperature reflectance, 3) minimum scan angle with high NDVI, 4) minimum scan angle with high NDVI and temperature reflectance, 5) minimum blue reflectance with high NDVI.

In this research, we use MODIS sensors satellite data for evaluation of the composite algorithms.

The MODIS data is a raster format image file where each pixel of the image is the reflectance value of a specific bandwidth for the location. MODIS sensor data contains 36 different bands, including visible red (band 1), near infra-red (band 2). MODIS has sensors in 3 different spatial resolutions, 250m^2 resolution (band 1-2), 500m^2 resolution (band 3-7), 1km^2 resolution (band 8-36), so each pixel data will be the average reflectance value for the location in the specified spatial resolution.

NDVI is a standard vegetation index defined by the following equation,

$$NDVI = \frac{NIR - R}{NIR + R} \qquad (1)$$

where R is band 1 (visible red) reflectance value, and NIR is band 2 (near infra red) reflectance value for the given location.

NDVI reflects the growth of vegetation, so for a given temporal interval the value is not expected to change drastically. It is also known that NDVI values become lower when clouds in the atmosphere interfere with the reflection. MVC with NDVI takes into account these 2 assumptions, and selects the highest NDVI value within a set temporal interval for the same location, to pick the best cloud-free data for the location within the temporal interval.

To create a 10-day composite image, assuming there is 1 MODIS reading every day for a total of 10 files, the maximum NDVI value is selected from the 10 different MODIS readings for the exact same location. The maximum NDVI marks the best cloud-free data for the temporal interval for the location, and the reading is copied to the composite image file for the same location. The reflective values of each of the different bands for the same location and day are also copied to the respective composite image files for each band. This is repeated for every location (pixel) in the MODIS NDVI image file to create a composite image for the specified temporal interval.

IV. PROPOSED METHOD

The composition method using minimum blue criterion from among high NDVI values is also widely used. This method is based on the observation that visible blue wavelengths are highly sensible to atmospheric interference, and the blue reflectance values increase with rise in atmospheric interference. Therefore, the clearest days should have the lowest blue reflectance readings. This method first selects a set of candidate readings with high NDVI values, and then selects the reading with the lowest blue value from among the candidates. The candidates are selected for example by selecting NDVI values within 80% range of the maximum NDVI for the temporal interval.

In this research we propose applying soft computing approach, namely fuzzy logic[3], in order to create a composition method which can be more easily tuned for specific regions.

In this paper we take the minimum blue criterion as the initial model. In the standard rule-based minimum blue criterion, there is a crisp criterion of high NDVI candidates (e.g. 80% of maximum NDVI) and crisp criterion of lowest blue value from among the candidate. In this standard crisp rule-based method, a very low blue value with 79% NDVI value will be discarded. Similarly, even if the maximum NDVI value has second lowest blue value, the maximum NDVI value will be discarded.

We extend the blue criterion composition algorithm by defining a fuzzy set of high NDVI values, and a fuzzy set of low blue values, and selecting the best value from the combined fuzzy set of high NDVI and low blue using fuzzy logic.

We set the fuzzy set *N* as the set of readings with high NDVI values and fuzzy set *B* as the set of readings with low blue values, defined by the membership function m_N and m_B on total space *X* and *Y* of NDVI and blue readings, respectively.

$$N = \int_X m_N / x \qquad x \in X \qquad (2)$$

$$B = \int_Y m_B / y \qquad y \in Y \qquad (3)$$

$$m_N : X \to [0,1] \qquad (4)$$

$$m_B : Y \to [0,1] \qquad (5)$$

The membership value or grade $m_N(x)$, $m_B(y)$ for reading *x* and y is similarly defined as below.

$$m_N(x) \in [0,1] \qquad (6)$$

$$m_B(y) \in [0,1] \qquad (7)$$

From fuzzy logic, the fuzzy set of readings with high NDVI values and low blue values are defined as the fuzzy intersection of set *N* and *B*, and given as below.

$$\begin{aligned} N \cap B \Leftrightarrow\ & m_{N \cap B}(x, y) \\ &= m_N(x) \wedge m_B(y) \\ &= \min\{m_N(x), m_B(y)\} \end{aligned} \qquad (8)$$

By defining an appropriate membership function for fuzzy set *N* and *B*, the reading with best value can be calculated as the reading with the highest grade in *N* ∩ *B*.

For this experiment, the membership grade for $m_N(x)$ and $m_B(x)$ was defined as below.

$$m_N(x) = \begin{cases} \dfrac{(x - T_N)}{(x_{MAXN} - T_N)}, & x \ge T_N \\ 0, & x < T_N \end{cases} \qquad (9)$$

$$m_B(y) = \begin{cases} \dfrac{(T_B - y)}{(T_B - y_{MINB})}, & y \le T_B \\ 0, & y > T_B \end{cases} \qquad (10)$$

x_{MAXN} is the maximum NDVI value, y_{MINB} is the minimum blue value, T_N is the threshold value for large NDVI candidates, T_B is the threshold value for low blue candidates.

V. RESULTS AND CONCLUSION

The proposed method was applied to create a monthly composite data for July 2001 over regions in Japan. This was compared with composite data for the same temporal interval and region using MVC with maximum NDVI. The proposed method was able to remove clouds successfully, and the final composite result was very close to that of standard MVC using maximum NDVI.

In this paper, an extension to minimum-blue criterion composition method for remote sensing data was proposed. The proposed method applies fuzzy set theory and fuzzy logic to facilitate parameter tuning, as well as produce a composite method allowing a more flexible selection of data for the composite image.

For future works, we need to closely examine the differences of output between the proposed method and standard method, and evaluate the effectiveness and accuracy of the proposed method.

VI. ACKNOWLEDGMENTS

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