Fractal Analysis of Scale Effect on Remote Sensing Images

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INTRODUCTION

The purpose of this study is to analyze the effect of scale on remote sensing analysis utilizing fractal analysis. The scale of a remote sensing image influences the measurement and analysis of objects in the image, and choice of appropriate scale or spatial resolution is a key parameter of effective analysis.

Fractal analysis methods, such as the Triangular Prism method or Windowed Fractal Brownian Motion method, seek to analyze an image using subpixel measurements and geometric, mathematical analysis. This study utilizes the Modified Triangular Prism Method (Sun et al. 2006) to measure the fractal dimension *D* of three remote images of the Grand Valley State University campus to assess the impact of scale on remote sensing analysis.

MATERIALS & METHODS

Three remote sensing images of Grand Valley State University's campus were utilized in this study, each with a varying spatial resolution. All images were clipped to the same extent with cloud cover <10%.

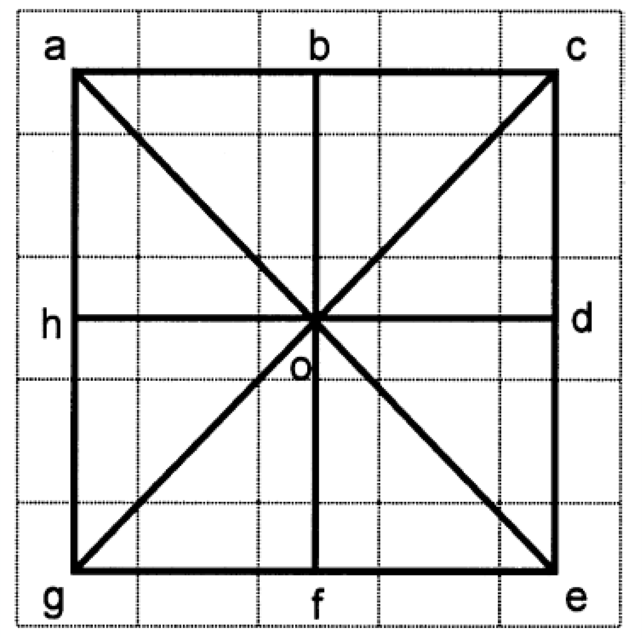
The images used in this study are as follows:

- GVSU Orthophoto imagery from 2018, with 3-inch resolution
- National Agriculture Imagery Program (NAIP) aerial imagery with 0.6- meter resolution
- PlanetScope satellite imagery with 3-meter resolution

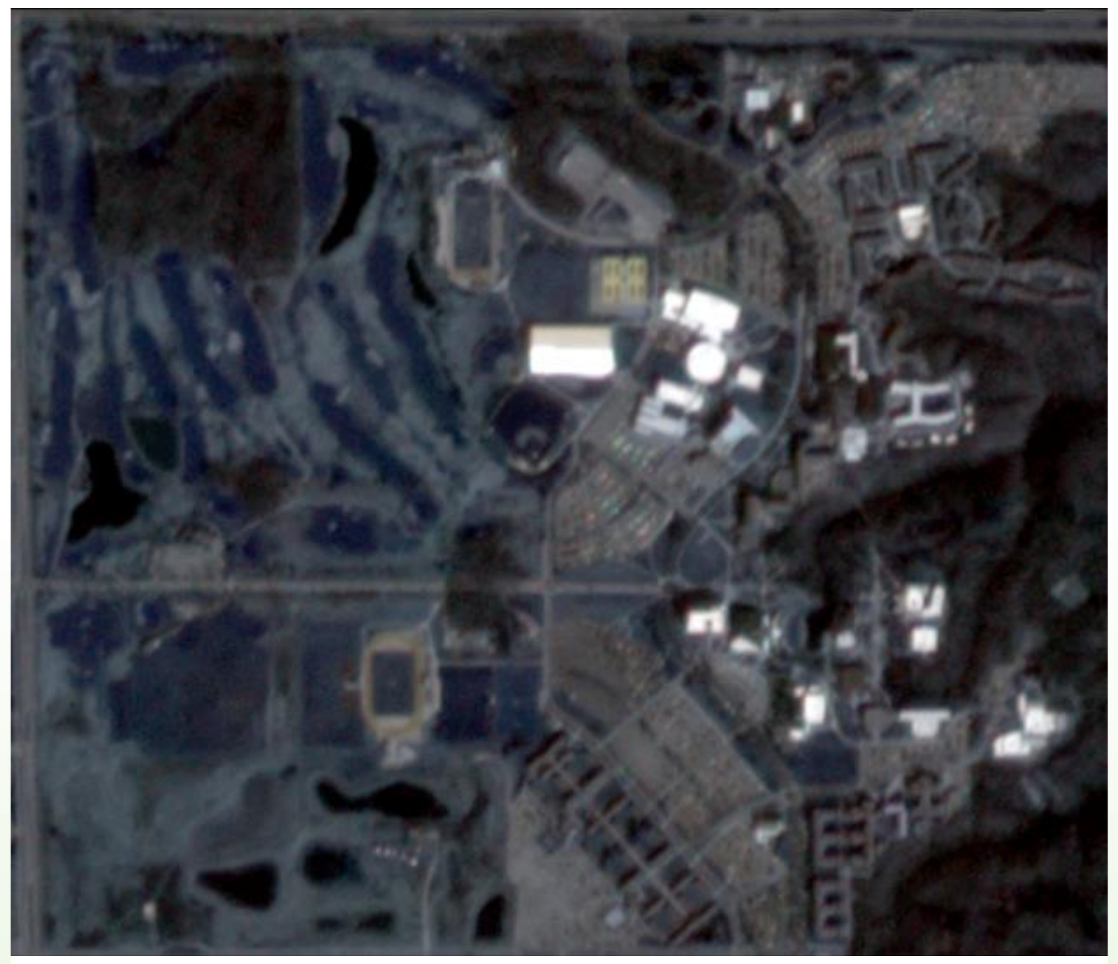
To analyze the fractal dimension *D* of these three images, the Modified Triangular Prism method proposed by Sun in 2006 is utilized. The Modified Triangular Prism method (MTPM) utilizes geometric calculation to estimate the complexity of terrain features in MATLAB, a programming and numeric computing platform.

The calculation of fractal dimension using the MTPM is itself an extension of the method utilized by Clarke in 1986.

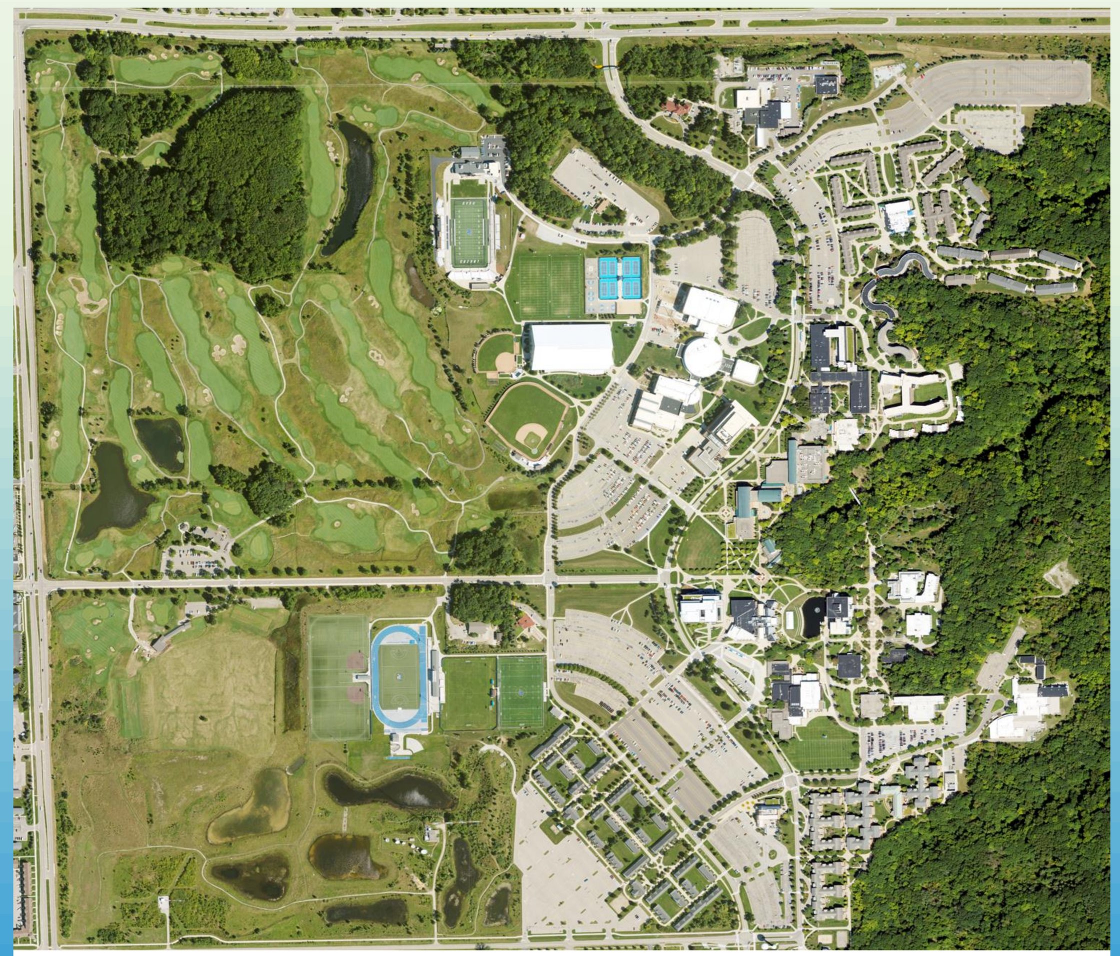
This method generates four triangular prisms, which can be used to calculate fractal dimension by averaging the elevations of the four corners to estimate the elevation of the center of the pixel, while the MTPM uses eight triangular prisms to calculate average digital elevation.



Layout of the pixel edge measurements used in calculation of fractal dimension *D*, Modified Triangular Prism Method: 8-Prism method (Sun et al., 2006)



The PlanetScope Satellite Image, fractal dimension *D* = 2.1199



The NAIP Aerial Image, fractal dimension *D* = 2.2308

The GVSU Orthophoto Image, estimated fractal dimension *D* = 2.2582

RESULTS

The Modified Triangular Prism method selects the elevations for averaging centroid approximation using the Eight Pixel method proposed by Sun: instead of averaging four corners, this method assesses the generated fractal dimension of analysis methods using eight points at the edges at corners of the pixel.

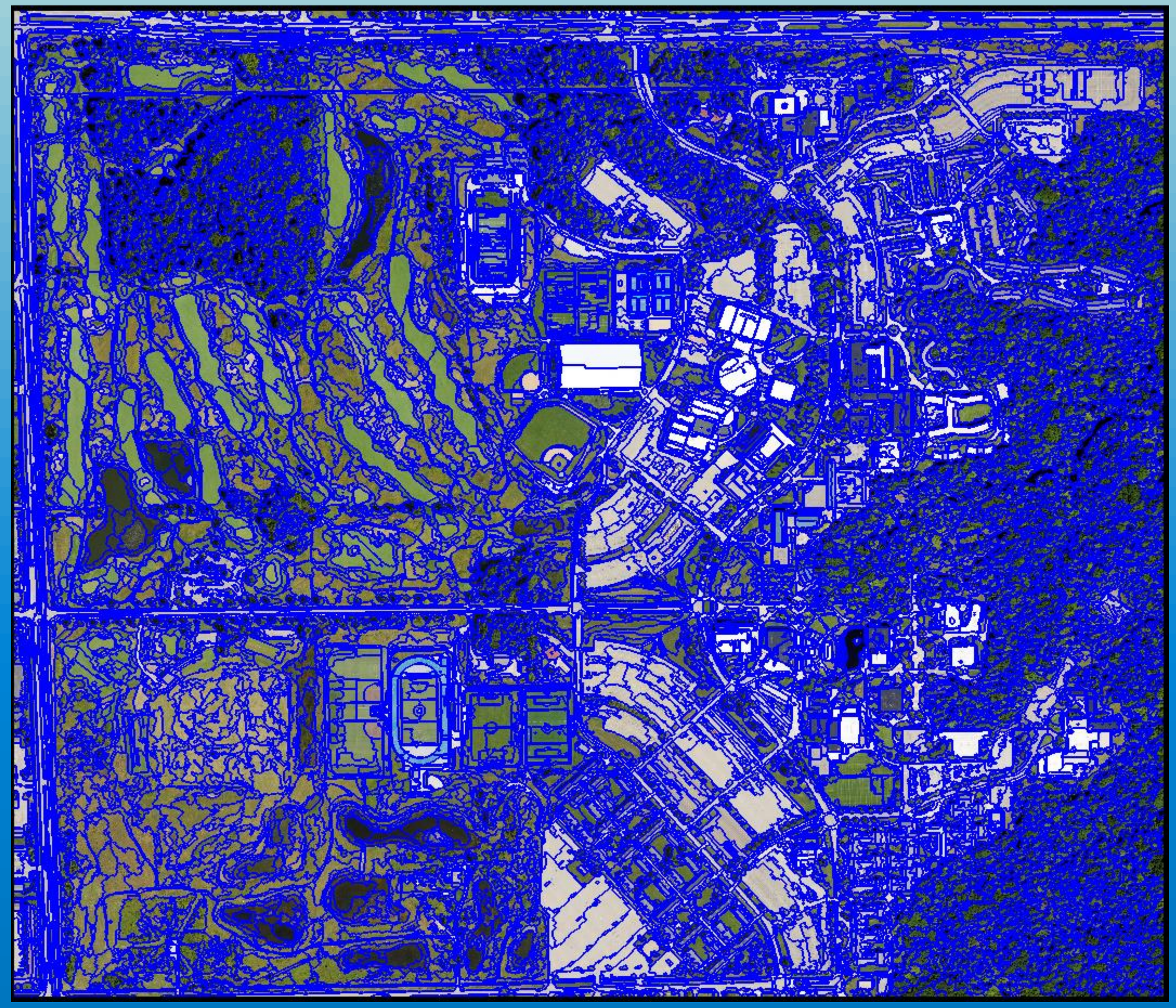
The fractal dimension *D* computed for each of the images are as follows:

- The NAIP Aerial Imagery: *D* = 2.2308
- The PlanetScope Satellite Imagery: *D* =2.1199

Alternative use of the Compression Dimension slope factor method (Chamorro-Posada 2016) estimates the fractal dimension *D* to be approximately 2.2582.

In analyzing remote sensing images with fractal analysis methods, a clear link between fractal dimension *D* and the scale of the image can be assessed. The relationship between the two does increase with resolution, however, the relationship is non-linear. **Benefits from increasing resolution decrease, especially as increases to file size and processing time are considered.**

The higher a fractal dimension, the more information complexity present in the subpixel calculations performed on the images.



Application of scale effect on object classification and segmentation techniques using eCognition's Fractal Net Evolution Approach

NAIP Aerial Image, segmented at a scale parameter of 42

CONCLUSIONS

While the sample size of this study is only three images, the use of fractal dimension as a predictor of appropriate scale is a useful technique in remote analysis. Several models already utilize the scale effect seen here, such as eCognition's Multiresolution Segmentation, which utilizes the Fractal Net Evolution Approach.

The field of remote sensing could benefit greatly from increased research and funding into computation and development of fractal analysis techniques: if an image could be appropriately assessed using its fractal dimension *D* at a high enough resolution, information at a subpixel level could be obtained for a variety of remote sensing applications, such as land cover analysis, spatial and spectral enhancement, and classification techniques.

Barriers to analysis include file size and cost or processing power: analysis of the orthophoto image could not be performed as the burden on system RAM was too high.

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