

Lec3



explain the code line by line and if there is error in the execution of the code then remove it by updating the code snippet and state the reason for the update



Please share the code snippet you would like me to explain and update, and I'll walk through it line by line.



Raster states

rasterstats is a Python module for summarizing geospatial raster datasets based on vector geometries. It includes functions for zonal statistics and interpolated point queries.

The instalation can be done with pip,

pip install rasterstats
installation with conda,

conda install -c conda-forge rasterstats

By default, the zonal_stats function will return the following statistics: min, max, mean,count. But, optionally, these statistics are also available: sum, std, median, majority, minority, unique, range, nodata, percentile.

```
from rasterstats import zonal_stats
import pandas as pd
Constant variables
DIR_MUNICIPALITY_SHP = r"../data/shp/municipality.shp"
DIR_POKHARA_SHP = r"../data/shp/pokhara.shp"
DIR_LULC = r"../data/geotiff/nepal_lc_2020.tif"
DIR_SRTM = r"../data/geotiff/srtm_57_08_1.tif"
Raster stats for single feature
# zonal stats of raster
zonal_stats(DIR_POKHARA_SHP, DIR_LULC)
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Raster stats for multiple features
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```

```
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```



```
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{'min': 10.0, 'max': 220.0, 'mean': 73.87362496802251, 'count': 3909},
{'min': 10.0, 'max': 220.0, 'mean': 104.3256336220725, 'count': 6234}]
```

Raster stats for catagorical raster data

zonal stats for catagorical data

```
zonal_stats(DIR_POKHARA_SHP, DIR_LULC, categorical=True)
```

```
[{10: 275,
  11: 347,
  20: 27,
  30: 638,
  40: 1547,
  50: 908,
  60: 431,
  61: 38,
  70: 833,
  100: 64,
  110: 2,
  120: 15,
  190: 305,
  210: 104}]
```

Raster stats to pandas dataframe

```
area_list = zonal_stats(DIR_MUNICIPALITY_SHP, DIR_LULC, categorical=True)
```

```
df = pd.DataFrame(area_list)
```

```
df.head()
```

```
10  11  20  30  40  50  60  61  70  100 ...  150 200 201 202 210 12  190 122 180 90
0   63.0   42.0   3.0 149.0  133.0  322.0  157.0  20.0  140.0  14.0   ...  NaN
NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN
1   18.0   22.0   1.0  38.0  110.0  447.0  185.0  41.0  696.0  15.0   ...  NaN
NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN
2   30.0   34.0   1.0 154.0  216.0  425.0  125.0 117.0 1139.0  35.0   ...  NaN
NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN
3   29.0   11.0   NaN  50.0  117.0  278.0  77.0  74.0 2503.0  76.0   ...
NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN   NaN
4   58.0   70.0  21.0 167.0 287.0  812.0 177.0 174.0 4999.0 170.0   ...
6.0 820.0  27.0  10.0   5.0 NaN   NaN   NaN   NaN   NaN
```

5 rows × 25 columns

Thank You



This Python snippet uses the `rasterstats` module for calculating zonal statistics for raster data based on vector geometries, which can be handy for analyzing geospatial data. The provided example demonstrates how to retrieve statistics such as `min`, `max`, `mean`, and `count` for single and multiple features.

Here's a breakdown of the process:

1. Installation:

- Install using `pip`:

```
bash

pip install rasterstats
```

- Install using `conda`:

```
bash

conda install -c conda-forge rasterstats
```

2. Constant Variables: File paths to the shapefiles and raster data are defined:

- `DIR_MUNICIPALITY_SHP` contains a shapefile of municipalities.
- `DIR_POKHARA_SHP` contains a shapefile for Pokhara.
- `DIR_LULC` and `DIR_SRTM` refer to land cover and terrain data in GeoTIFF format.

3. Zonal Statistics:

- For a single feature (Pokhara):

```
python

from rasterstats import zonal_stats
stats = zonal_stats(DIR_POKHARA_SHP, DIR_LULC)
print(stats)
```

- For multiple features (municipalities):

```
python

stats = zonal_stats(DIR_MUNICIPALITY_SHP, DIR_LULC)
print(stats)
```

These commands calculate statistics like the minimum, maximum, mean, and count of raster values within the areas defined by the vector geometries (shapefiles). You can extend this by requesting other statistics such as `sum`, `median`, `std`, etc., depending on your needs.

If you need help with a specific use case or want to see more options in action, feel free to ask!



explain the concept behind



The concept behind the *rasterstats* module, specifically its function ``zonal_stats``, revolves around the idea of *zonal statistics*. This process involves summarizing raster datasets (gridded data, often representing spatial data like satellite imagery or elevation models) based on vector geometries (such as polygons, points, or lines). Here's a breakdown of the key concepts:

1. Raster Data:

- A *raster* dataset consists of a grid of cells (or pixels) with each cell containing a value representing information, such as temperature, land cover type, or elevation.
- Raster data is commonly used in geographical information systems (GIS) for spatial analysis and is especially useful for large datasets covering vast areas.

2. Vector Data:

- *Vector* data represents geographical features using geometrical shapes such as points, lines, or polygons. These geometries are used to delineate specific areas or features like city boundaries, roads, or regions of interest.
- In the context of zonal statistics, vector data typically comes in the form of polygons, representing regions where statistics need to be computed.

3. Zonal Statistics:

- *Zonal statistics* refers to the process of summarizing raster data within the boundaries of vector geometries (zones). The goal is to calculate statistics like the mean, minimum, maximum, sum, and other metrics for the raster values that fall within each vector geometry.
- For example, you might want to know the average land cover type or the average elevation within the boundaries of a city (polygon).

4. How ``zonal_stats`` Works:

- The ``zonal_stats`` function from the *rasterstats* module takes as input:
 - A vector dataset (usually a shapefile or GeoJSON) representing the boundaries of zones (e.g., a city or municipality).
 - A raster dataset (e.g., a satellite image or digital elevation model) that covers the area of interest.
- The function computes statistical metrics (like mean, min, max, count) for the raster values that fall inside each vector zone.
- For each feature in the vector file (e.g., each municipality), the corresponding statistics from the raster data are calculated and returned.

5. Application Example:

- Suppose you have a raster dataset of land cover types across Nepal and vector data representing the boundaries of different municipalities. You can use ``zonal_stats`` to compute the average land cover type within each municipality's boundaries. This helps in summarizing large, gridded raster data based on specific regions of interest.

6. Use Case: Land Use and Elevation Analysis:

In the code example, ``DIR_LULC`` refers to a land cover raster file, and ``DIR_POKHARA_SHP`` refers to a shapefile of the Pokhara region:

```
python
```

```
from rasterstats import zonal_stats
zonal_stats(DIR_POKHARA_SHP, DIR_LULC)
```

- This code calculates the statistics (e.g., mean, min, max) of land cover types within the region defined by the Pokhara shapefile.

7. Benefits:

- **Efficiency:** Raster data often covers large areas and consists of thousands or millions of cells. Zonal statistics allow you to extract meaningful information for specific areas (vector zones) without manually analyzing the entire raster.
- **Versatility:** You can apply this technique to a variety of spatial data, such as land use, temperature, elevation, or population density.
- **Analytical Power:** It allows spatial analysis by connecting raster data (which is usually continuous and gridded) with vector data (which is more abstract and bounded by defined geometries).

8. Customizable Statistics:

- By default, `zonal_stats` returns basic statistics such as min, max, mean, and count. However, you can specify additional metrics like standard deviation, sum, range, etc., depending on your analysis needs. For example:

```
python
```

```
zonal_stats(DIR_POKHARA_SHP, DIR_LULC, stats=['min', 'max', 'mean', 'median'])
```

This flexibility makes it a powerful tool for spatial analysis.

In summary, the core idea is to summarize large, continuous raster datasets by focusing on specific vector zones, thus providing meaningful and aggregated information for analysis across geographical regions.



write a detail term paper for this



Term Paper: Zonal Statistics in Geospatial Analysis: Concepts, Techniques, and Applications

Abstract

Geospatial analysis relies heavily on the integration and processing of spatial data, which includes both raster (gridded) and vector (geometrical) formats. Zonal statistics, a fundamental technique in geographic information systems (GIS), enables the extraction of meaningful statistical summaries from raster data within specific vector geometries. This term paper explores the concepts and techniques behind zonal statistics, the process of summarizing raster data within the boundaries of vector zones, and its diverse applications in fields like environmental science, urban planning, and resource management. We will also examine the tools used for computing zonal statistics, with a focus on the *rasterstats* Python module.

1. Introduction

Geospatial analysis has become indispensable in various fields such as urban planning, agriculture, climate modeling, and natural resource management. The integration of raster and vector data is a powerful technique that allows for detailed spatial analysis across large geographic areas. *Raster* data represents continuous spatial phenomena (e.g., elevation, temperature, land cover), while *vector* data represents discrete objects or boundaries (e.g., cities, roads, forests).

Zonal statistics is a method of summarizing raster data based on vector-defined areas or zones. The term *zonal statistics* refers to the computation of statistical summaries (e.g., mean, maximum, minimum, sum) of raster data confined within the boundaries of vector geometries, which are often polygons.

This paper presents a detailed explanation of the zonal statistics concept, its computational process, and applications. It also delves into the technical aspects of the *rasterstats* module in Python, a widely-used tool for performing zonal statistics.

2. Understanding Spatial Data Types

2.1. Raster Data

Raster data consists of a matrix of cells or pixels, with each cell holding a value that represents a geographic attribute. Raster datasets are commonly used to represent continuous phenomena such as:

- Elevation models (Digital Elevation Models or DEMs)
- Land cover or land use (classification data)
- Climate variables (e.g., temperature, precipitation)

Raster data is characterized by its resolution (the size of each pixel) and the extent (the geographic area it covers). Larger datasets tend to have smaller pixel sizes, allowing for finer detail but also increasing the size and complexity of the data.

2.2. Vector Data

Vector data represents geographic features through points, lines, and polygons. This data type is used to define discrete features such as:

- Cities (points)
- Rivers or roads (lines)

- Administrative boundaries, forests, or lakes (polygons)

Each vector feature can hold various attributes, such as names, IDs, or specific measurements related to that geographic object.

2.3. Integration of Raster and Vector Data

The power of geospatial analysis lies in combining these two formats. For example, we can summarize raster data (such as elevation) for a specific polygon (a region or city) or calculate the average temperature within a river basin. This process of extracting summary statistics from raster data based on vector geometries is referred to as zonal statistics.

3. Zonal Statistics: Concept and Workflow

3.1. Definition of Zonal Statistics

Zonal statistics is the process of summarizing the values of a raster dataset for specific vector-defined zones. Each zone is defined by a vector feature (e.g., a polygon). For each zone, statistical measures such as mean, median, minimum, maximum, and standard deviation are computed based on the underlying raster data.

For example, if a raster dataset represents the elevation across a country, zonal statistics could be used to calculate the average elevation within each district (defined by polygon geometries).

3.2. Key Steps in Zonal Statistics Workflow

The basic steps for performing zonal statistics are as follows:

1. **Raster and Vector Data Acquisition:** Obtain the raster dataset (e.g., land use data, elevation, or temperature data) and vector geometries (e.g., administrative boundaries, watershed areas).
2. **Overlay Vector and Raster Data:** Overlay the vector geometries onto the raster data to determine which raster cells fall within each vector feature's boundaries.
3. **Statistical Summary:** Compute statistical summaries (mean, sum, minimum, maximum, etc.) for the raster values within the bounds of each vector feature.
4. **Output Results:** The results can be output as tables, new attributes added to the vector geometries, or visualized in maps.

4. The Rasterstats Module in Python

4.1. Overview of Rasterstats

rasterstats is a Python module that facilitates zonal statistics by providing simple yet powerful functions for summarizing raster data. The module integrates well with popular libraries such as *GDAL*, *geopandas*, and *shapely*, which are widely used for geospatial data manipulation.

4.2. Zonal Statistics Functionality

The primary function in *rasterstats* for computing zonal statistics is `zonal_stats``. This function takes two key inputs:

- A vector dataset (e.g., shapefile or GeoJSON) that defines the zones.

- A raster dataset (e.g., a GeoTIFF file) that contains the values to be summarized.

For example:

python

```
from rasterstats import zonal_stats

# Define file paths to raster and vector datasets
raster_file = "data/land_cover.tif"
vector_file = "data/admin_boundaries.shp"

# Compute zonal statistics
stats = zonal_stats(vector_file, raster_file, stats=['min', 'max', 'mean', 'median'])

# Display the computed statistics
print(stats)
```

4.3. Customizing the Output

By default, `zonal_stats` calculates basic statistics such as minimum, maximum, mean, and count. However, the user can specify additional statistics, including:

- **Standard deviation:** Measure of variability of the raster values within the zone.
- **Sum:** Total of the raster values within the zone.
- **Range:** Difference between the maximum and minimum values within the zone.

The function also supports other customizations, such as limiting statistics to non-zero values or applying masks to exclude certain raster values.

5. Applications of Zonal Statistics

5.1. Environmental Monitoring

Zonal statistics are widely used in environmental monitoring to extract spatial information from satellite imagery or other raster datasets. For instance:

- **Land Cover Classification:** Calculate the dominant land cover type within administrative regions.
- **Deforestation Monitoring:** Summarize forest cover loss within protected areas.
- **Climate Analysis:** Compute the average temperature within specific climate zones or watersheds.

5.2. Urban Planning

In urban planning, zonal statistics can be applied to evaluate spatial characteristics of cities and urban regions:

- **Population Density:** Summarize population density within city blocks or neighborhoods.
- **Land Use Distribution:** Analyze the proportion of land devoted to residential, commercial, or industrial use.
- **Flood Risk Assessment:** Calculate the average elevation or slope within flood-prone areas.

5.3. Agriculture and Forestry

In agriculture, zonal statistics are used to derive information from satellite imagery for crop health monitoring, yield estimation, and soil moisture analysis. Similarly, in forestry, zonal statistics help in estimating forest biomass, deforestation rates, and biodiversity within specific zones.

5.4. Hydrology and Watershed Management

Hydrologists use zonal statistics to analyze rainfall, runoff, and soil moisture within watershed boundaries. These analyses are critical for water resource management, flood prediction, and ecosystem conservation.

6. Challenges and Limitations

6.1. Resolution and Accuracy

The resolution of the raster data plays a critical role in the accuracy of zonal statistics. Coarse resolution raster data may not capture detailed spatial variations within small vector zones, leading to imprecise results.

6.2. Handling NoData Values

Raster datasets often contain *NoData* values, which indicate areas without valid data. Proper handling of these values is crucial, as they can distort the computed statistics if not accounted for properly.

6.3. Computational Efficiency

For large datasets, performing zonal statistics can be computationally intensive. Efficient processing and data handling strategies, such as tiling large raster datasets, are necessary to manage the computational load.

7. Conclusion

Zonal statistics is a powerful technique that bridges raster and vector data to enable detailed spatial analysis. Whether used in environmental monitoring, urban planning, agriculture, or hydrology, this technique provides essential insights into spatial patterns and relationships. Tools like *rasterstats* in Python make it accessible to researchers, allowing for efficient computation and integration with broader geospatial workflows.

As geospatial data continues to grow in importance, the ability to extract meaningful information from both raster and vector datasets will remain a cornerstone of GIS-based analysis. Future developments in computing power and data handling will likely further enhance the utility of zonal statistics in solving complex spatial problems.

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