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Digital Maps – British Columbia

DSMM - Maple Mapping

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I. Project Overview

The Digital Maps of British Columbia project, undertaken in collaboration with the National Geographic Society, aims to create accurate and visually captivating digital maps of the British Columbia region. Our team, led by Maple Mapping, will leverage expertise in geographic analysis and digital mapping services to achieve this goal. Our primary objective is to create highly precise digital maps that capture essential topographical elements, soil types, and other relevant features of British Columbia. These maps will serve as valuable resources for research and exploratory educational activities within Canada.

II. Data Requirements and Data types

The data for this project needs to be accurate and reliable geospatial data for producing actionable maps. The data requirements are as follows:

1. **High-resolution satellite imagery**: High resolution images covering British Columbia offering detailed visual information about land cover, land use, and environmental features.
2. **Drone footage**: Aerial imagery captured by drones, providing high-resolution views of specific locations and features not easily observable from satellite imagery.
3. **Sensor Data**: Deployment of environmental sensors measuring parameters such as temperature, humidity, and air quality to enhance map accuracy and support environmental monitoring efforts.
4. **Historical mapping information**: Access to historical records, including audio recordings and images, relevant to the region's geography and cultural heritage, aiding in understanding past landscapes and human activities.
5. **Topography Information**: Detailed elevation maps depicting terrain heights and variations across British Columbia. Identification and characterization of prominent landforms such as valleys, plateaus, and ridges.
6. **Natural Features**: Mapping of water bodies including rivers, lakes, and reservoirs, along with tributaries and extents. Identification and delineation of forested areas, including tree species composition and canopy coverage. Identification and classification of mountain ranges, hills, and peaks, providing insights into the region’s topography.

The data types employed to fulfill the aforementioned data requirements include:

1. **Raster data**: Raster data represents spatial information as a grid of cells or pixels, where each cell contains a single value representing a specific attribute or phenomenon across a geographic area.
    - Satellite Imagery: Represented as pixel values with different spectral bands (e.g., RGB, infrared).
    - Elevation models: Digital elevation models (DEMs) in raster format.
    - Soil maps: Soil type distribution as raster layers.
2. **Vector data**: Vector data represents spatial information using points, lines, and polygons to define features such as points of interest, roads, and administrative boundaries with geometric precision and attribute data attached to each feature.
    - Point Data: Coordinates of specific features (e.g., mountain peaks, landmarks).
    - Line Data: Rivers, roads, trails, and other linear features.
    - Polygon Data: Representing areas (e.g., forest boundaries, administrative regions).
3. **Tabular data**: Tabular data organizes information into rows and columns, typically representing individual observations or entities with associated attributes or variables in a structured format suitable for analysis and manipulation.
    - Attributes: Associated information for each feature (e.g., soil properties, elevation values).
    - Metadata: Descriptions, timestamps, and sources details.
4. **Time Series data**: Time series data consists of sequential observations recorded over time intervals, representing the evolution or variation of a particular variable or phenomenon over a continuous time period.
    - Historical Trends: Changes in land cover, vegetation, or other features over time.
    - Sensor readings: Temporal variations in environmental parameters.

III. COMPLEXITIES

1. **Data Quality**: Despite advancements in satellite sensor technology, high-resolution imagery may still contain artifacts such as noise, atmospheric effects, and sensor distortions. Ensuring data quality and pre-processing satellite imagery to mitigate these artifacts is crucial for reliable analysis.
2. **High Dimensionality**: High-resolution satellite imagery is characterized by high dimensionality due to the large number of pixels and spectral bands in each image.

Analyzing such complex data requires advanced processing techniques capable of handling large datasets efficiently.

IV. Unique characteristics

1. **Continuous Monitoring**: Satellites can capture imagery at regular intervals, enabling continuous monitoring of changes over time and providing valuable data for long-term trend analysis and forecasting.
2. **Global Coverage**: High-resolution satellite imagery provides near-global coverage of the Earth's surface, enabling analyses at various spatial scales, from local to global.

V. AI Technologies

Artificial Intelligence (AI) technologies play a pivotal role in unlocking insights from geospatial data to address complex challenges in urban planning, environmental management, disaster response, and beyond. Several of these technologies offer significant utility, including:

CHANGE DETECTION

Change detection is a crucial process in remote sensing and GIS (Geographic Information Systems) that involves identifying and quantifying changes that have occurred on the Earth's surface over time. This technique plays a significant role in various fields such as urban planning, environmental monitoring, agriculture, forestry, and disaster management.

Definition: Change detection typically involves comparing multiple images of the same geographic area captured at different times, such as satellite or aerial imagery acquired during different seasons or years. Changes can be classified into different categories, including land cover changes (e.g., urban expansion, deforestation, agricultural encroachment), infrastructure changes (e.g., road construction, building demolition), natural phenomena (e.g., floods, wildfires, erosion), and environmental changes (e.g., vegetation dynamics, land degradation).

Methods: Change detection methods involve analyzing sequential data to identify and quantify alterations in geographical features over time.

1. **Pixel based detection:** This method compares individual pixels in the images to detect changes based on differences in pixel values, such as spectral properties or indices (e.g., NDVI for vegetation change). Common techniques include image differencing, image rationing, and thresholding.

2. **Object-based Change Detection:** Instead of analyzing individual pixels, this method groups pixels into objects or regions based on spatial and spectral characteristics and detects changes at the object level. Object-based methods are more robust to noise and provide more meaningful change information.
3. **Machine Learning Approaches:** Machine learning algorithms, such as support vector machines (SVM), random forests, and convolutional neural networks (CNNs), can be trained to classify changes automatically based on labeled training data. These approaches can handle large datasets and complex patterns but require substantial training data and computational resources.

Metrics: Various metrics can be used to quantify the magnitude and significance of changes detected, including change magnitude, change intensity, change frequency, change direction, and change probability. These metrics help assess the spatial and temporal dynamics of changes and prioritize areas for further analysis or intervention.

GEOSPATIAL ANALYSIS

Geospatial analysis encompasses a diverse set of techniques and methodologies for extracting insights from spatial data, enabling a deeper understanding of the Earth's surface and its features.

Definition: Geospatial analysis begins with processing and organizing spatial data, which can include satellite imagery, aerial photographs, GPS data, LiDAR scans, and GIS datasets. This involves data cleaning, transformation, and integration to ensure consistency and compatibility across different sources.

Methods and Techniques: Before delving into various spatial analysis techniques, it's essential to understand the breadth and depth of geospatial analysis, which encompasses a diverse set of methodologies for extracting insights from spatial data.

1. **Spatial Statistics:** Spatial statistical techniques, such as spatial autocorrelation, hotspot analysis, and spatial interpolation, are used to analyze the spatial distribution, patterns, and relationships of geographic features. These methods help identify clusters, trends, and anomalies within spatial data.
2. **Geo Statistics:** Geostatistical techniques, such as kriging and variogram analysis, are used to analyze and model spatially correlated data, such as environmental variables or terrain elevation. These methods help predict values at unsampled locations and quantify uncertainty in spatial predictions.
3. **Remote Sensing Analysis**: Remote sensing analysis utilizes satellite or aerial imagery to extract information about the Earth's surface, such as land cover, vegetation health, and surface temperature. It involves image processing techniques, such as classification,

change detection, and feature extraction, to derive meaningful insights from remote sensing data.

IMAGE CLASSIFICATION

Image classification is a foundational task in computer vision and remote sensing, aiming to categorize pixels or image regions into predefined classes based on their spectral or spatial characteristics. This technique serves as a cornerstone for various applications in land cover mapping, vegetation monitoring, urban planning, and disaster management.

Definitions: Image classification involves training machine learning algorithms, typically supervised classifiers like Support Vector Machines (SVM), Random Forests, or Convolutional Neural Networks (CNNs), on labeled datasets of images with known classes. Through this process, the algorithm learns to recognize patterns and features associated with different classes, enabling it to classify unseen images accurately.

Methods and Techniques:

1. **Supervised Learning:** In supervised image classification, the algorithm learns from a labeled dataset, where each image is associated with a corresponding class label. The algorithm is trained to map input images to their respective classes based on the features extracted from the images.

2. **Feature Extraction:** Feature extraction involves identifying relevant features or characteristics from the input images that distinguish between different classes. These features can include spectral information (e.g., intensity, color) and spatial information (e.g., texture, shape).

3. **Classification Algorithms:** Various machine learning algorithms are used for image classification, including:

    - Support Vector Machines (SVM): SVMs classify images by finding the optimal hyperplane that separates different classes in feature space.
    - Random Forests: Random Forests use an ensemble of decision trees to classify images based on a set of features.

- Convolutional Neural Networks (CNNs): CNNs are deep learning models specifically designed for image classification, capable of automatically learning hierarchical features from raw pixel values.

VI. Use Case Scenarios

1. The National Geographic Society requires detailed land cover maps of British Columbia to support conservation efforts and wildlife habitat monitoring.

   Applications: High Resolution Satellite Imagery combined with Image Classification algorithms can be used to classify land cover types such as forests, water bodies and urban areas. Machine learning models trained on labeled satellite images can automatically classify different land cover classes, enabling the creation of accurate and up-to-date land cover maps for the region.

2. The National Geographic Society aims to document and monitor changes in remote and inaccessible areas of British Columbia, such as mountainous terrain and dense forests.

   Applications: Drones equipped with cameras can capture high-resolution aerial imagery of these areas. Object detection algorithms can analyze drone footage to identify and track changes in vegetation, detect landforms, and assess habitat conditions. This information can be used to update maps, monitor ecosystem health, and support conservation efforts in these remote regions.

3. The National Geographic Society needs to monitor environmental variables such as temperature, humidity, and air quality across different regions of British Columbia to understand the impacts of climate change and human activities.

   Applications: Environmental sensors deployed across the region can collect real-time data on environmental parameters. Machine learning algorithms can analyze sensor data to detect anomalies, identify trends, and predict future environmental conditions. This information can be integrated with digital maps to provide spatially explicit insights into environmental changes and inform conservation strategies.