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INTEGRATION OF REMOTE SENSING DATA WITH GEOGRAPHIC INFORMATION SYSTEM (GIS): APPLICATIONS AND CHANGE DETECTION TECHNIQUES

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ABSTRACT

Remote Sensing and Geographic information System together comprise of Geographic Information Science (GIScience) which is a core research field that tries to emphasis on advanced geographic concepts in Geographic Information System and examines the impact of GIS on individuals and society as a whole and re-examines the themes with incorporation of most recent cognitive and Information Science. The Geographic Information System can be defined as a Computer based system and a tool, both hardware, software and procedures, which manages geospatial data, solves spatial problems, and supports collection, storage, transformation, analyzing, retrieving and display of data in a well desired manner. The integration of GIS and Remote Sensing is a field of research and several implementations have been developed to gain the maximum throughput out of these collective fields as these techniques have their own data analysis and data representation methods. The application domain of remote sensing is from a base layer for GIS to the development of thematic datasets, obtaining and extracting data from imagery and generation of unique spatial datasets. In my paper I have focused on the integration of both the fields along with its usage in Analysis and Modelling and also some models of error sources due to the integration of interface of the two techniques. The paper also describes some error sources while integration as GIS and remote sensing both are subject to errors and uncertainty. The paper has discussed some Change Detection Techniques used in the modern sciences with their comparison.

In GIS all the images positioned should be accurate and correctly positioned. All the data layers should be described correctly, must be registered to one another and must be Georeferenced to a specific map projection and coordinate system. Base maps are the frame of reference for positioning and mapping. Remote sensing is the source of thematic data especially data on land use, land cover characteristics and surface elevation. So deriving thematic geospatial data through remote sensing is a big task. The images taken from remote sensing has spatial displacements of objects and variations. Such displacements should be removed in order to create orthorectified image. So for this purpose the data required should be imported from GIS only. Hence they have to be integrated with each other. So for further analysis the output data is fed back into the GIS system and used for other purposes.

KEYWORDS

Geographic Information System, Remote Sensing, Error sources, Change Detection Techniques, Sources of error

1. INTRODUCTION

Global warming is the increase of the Earth's average surface temperature due to the effect of Greenhouse gases and it is a global environmental problem resulting in a global climate change. The concentration of carbon dioxide in the atmosphere is said to be accelerating at an annual rate of 1.91 parts per million (ppm) [1]. It has increased in volume by 30% since the industrial revolution and its tripling is expected at the end of 21st century [2]. It manifests itself in different spatio-temporal dimensions and scales [3]. It results in significant land use change and land cover shift and modify the capacity of the ecosystem to provide ecosystem goods and services [4]. Eventually human survival is at threat.

The climate conditions is changing continuously and scientists and policy makers have been searching ways of tackling menacing threat of climate change [3]. Climate change adaptation includes the ways which describes the living with the changing environmental conditions.

We humans have to understand the change. Therefore it requires a need of data collection, methods and techniques through which processing and understanding of the change can be faster, reliable and economical. The Geographic Information System can be defined as a Computer based system and a tool, both hardware and software and procedures, which manages geospatial data, solves spatial problems, and supports collection, storage, transformation, analyzing, retrieving and display of data in a well desired manner. The Geographic Information System along with Remote Sensing (GISciences) are the fields which helps us to study and understand the environmental changes along with its future consequences on living things as well as on non-living things. The application domain of remote sensing is from a base layer for GIS to the development of thematic datasets, obtaining and extracting data from imagery and generation of unique spatial datasets. Remote Sensing and GIS tools helps us to detect and forecast the possible effects so that measure steps could be taken before disaster occurs and therefore minimum loss of environmental property.

2. INTEGRATION OF GIS WITH REMOTE SENSING AND ITS APPLICATIONS

Remote Sensing can be defined as the science of obtaining the information about any object, phenomenon or any field through a device which is actually not in touch (physical contact) with the object. The data collected is represented in the form of a photograph for the purpose of achieving the temporal information and identifying the surface objects. Geographic Information System provides a tool for collection, management, storage, manipulation and display of the remotely sensed data, spatial and non-spatial data for modelling purposes.

2.1. Agricultural Resource Management

Satellite data provide a real-time assessment of crop condition. We can combine Landsat7 ETM+ images and can derive distributed data such as sowing dates, irrigation practices, soil properties, depth to groundwater and water quality as inputs in exploring water management options. This approach was used in Kaithal, Haryana, India during 2000–2001 dry season. Also “Pilot Project” is a part of Natural Resource Information System for Panchmahals located in Gujarat, which focuses on soil and water conservation plan. It uses some modern techniques with the integration of GIS and RS Techniques [5].

2.2. Flood Monitoring System

Islam and Sado developed flood hazard maps for Bangladesh using RS data for the Historical event of the 1988 flood with data of elevation height, and geological and physiographic divisions. They successfully demonstrated the potential of using GIS for flood disaster Management for Allahabad Sadar Sub-District (India) [5].

2.3. Contact Tracing of EBOLA Virus and EBOLA Virus Disease (EVD) Case Management System

The integration of Remote sensing techniques with GIS is not only used in Geographical context but also in environmental context including Medical Sciences and tools. Recently the outspread of ebola virus caused a heavy loss of lives all over the world. More than 100 countries were affected

From this virus. The Geoinformatics provided a decision support system using spatial and geographical distribution system. This system simulated the EVD control activities. The whole data capturing, affected area detection and storing the data was given by the system. It also has the capability of predicting the affected population in upcoming years.

In an effort to streamline management of the disease outbreak WHO (World Health Organization) developed "Field Health Management System Software". NAVRCGIS4ebola is an integrated Geoinformatics tool to support outbreak response activities in terms of case and contact data collection, analysis and production of related reports. [6]

The basic flow of the system is as follows:

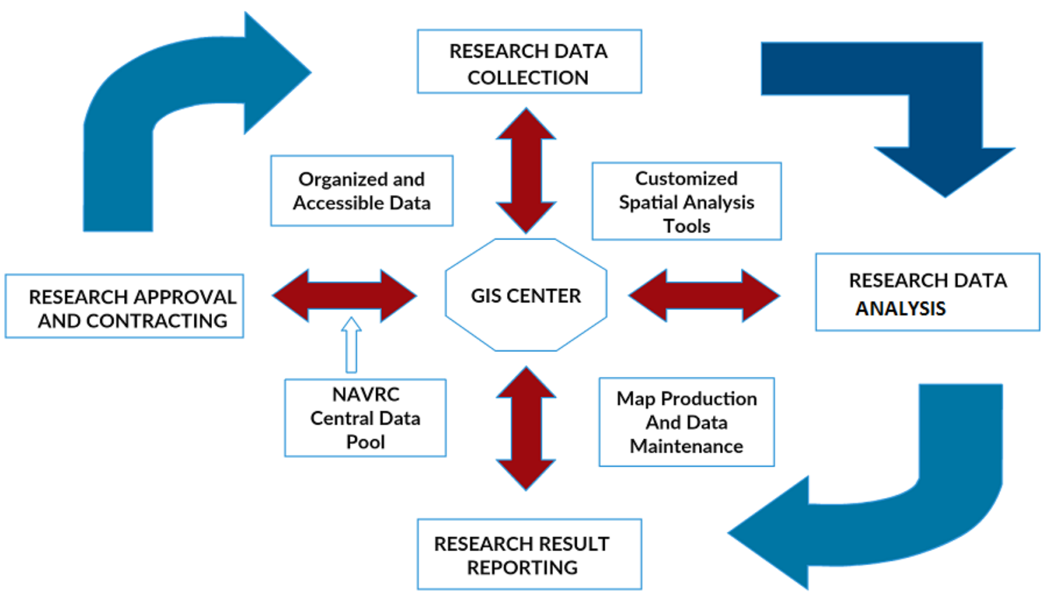

Figure1 Workflow for Integrating GIS and Remote Sensing in Contact Tracing and EVD Case Management [6]

2.4. Applications in Water Management

The Water management deals with control, distribution and allocation of water flows. So locating the correct water sources is the main task. Here the integrated GIS and Remote Sensing tools are used which provides the position within the catchment and spatial interrelationships between physical catchment characteristics such as land use, water bodies and vegetation cover. Water Management is a system developed coupling the elements such as databases on thematic maps, satellite images, hydrologic time series data, a spatial analysis module with a link to hydraulic simulation models which may contain methods for multi objective decision making.

Satellite Remote Sensing is used to detect water bodies using satellite imagery depending on spatial resolution of the sensors used. Some of the sensors used to detect water bodies and their characteristics are Landsat MSS, Landsat TM, SPOT-MLA, SPOT-PLA and IRS PAN.

The spatial resolution of Landsat MSS is 80 meters with a mapping size of 2.5 hectares and that of Landsat TM is 0.36 hectares with a spatial resolution of 30 meters.

The integrated system is also used in Flood Plain Management. Conventional methods are less responsive and have many limitations. The use of microwave remote sensing has added a new dimension to flood inundation studies as it has solved the problem of cloud cover which often affected the availability of satellite images during the floods in case of optical remote sensing data [5]. The integrated system is used in flood inundation mapping, monitoring drainage during floods, flood plain zonation and forecasting. Repetitive coverage of satellite imagery helps in monitoring shifting course and to build up historical records [5].

These techniques play an important role in irrigation command areas by providing assessment of surface water resources, locating crop inventories, detecting canal seepage, performing the proper irrigation scheduling, characterizing types of soils, prediction of water table depths and detection of waterlogged lands.

3. ERROR SOURCES

As the technology is advancing we are introduced with more techniques that introduce us with the errors in past. These techniques help us in detection of errors more precisely as compared to the techniques used in the past. So for this purpose we have the advanced integrated GIS and Remote Sensing techniques. But GIS and remote sensing both are subject to errors and uncertainty.

3.1. Positioning Error

Several sources of error is possible when we are integrating GIS with Remote Sensing. So in general the error classes can be divided into instrumental errors and method errors. There are different types of error which directly or indirectly affects the output. Also we are dealing with pixels where misclassification of pixels is a common cause of error which directly affects the marginal boundaries of pixels and hence less reliable output. So accuracy plays an important role in the reliability of the acquired data. Horizontal accuracy for map products must be less than 10% of the tested points to reach a maximum error of 0.85 cm at scales greater than 1:20,000.
For maps at scales 1:20,000 or less the minimum admissible error is 0.51 mm [7]. The map standard deviation can be used as a map accuracy criteria.

$$d= \sum_{i=1}^{n} \left(\frac{li}{n}\right)^{0,5}$$

Where d= standard deviation
li= point error
n= total number of points

3.2. Data Error Classification

The thematic classification of data can be used for accuracy assessment. This method is based on comparing different classes of data. We select different classes of data and compare them with the reference data. The reference data is also known as the ground truth. In every class some representative pixels are present and these pixels are selected for comparison with the ground truth. By this method we can get the percentage of the correctly matched pixels and hence accuracy of the system can be assessed. But the drawback of this method is that large number of pixels can be selected from a large class but if a smaller class is present then there is a probability that its pixels may not be shown at all. The solution to this problem could be the stratified random sampling in which a set of strata is predefined and the random sampling is carried out in each of these collections containing the classes [7]. A regular grid can be used or a random selection of pixels in each class, in order to assess the class accuracy. The estimated accuracy for a class can be calculated as follows [8]:

$$\rho\left\{-z_{\frac{\alpha}{2}} < \frac{x - n\theta}{\sqrt{n\theta(1-\theta)}} < z_{\frac{\alpha}{2}}\right\} = 1 - \alpha$$

Where x= number of pixels which are correctly identified
n= total number of pixels present in the sample space
θ= the map accuracy

1- α= the confidence level (limit) imposed by the analyst.

3.3. Environmental Conditions

The environmental factors must be taken into account as most of them are dynamic in nature. They keep changing with respect to time. These factors may include environmental conditions, weather conditions, soil characteristics, rain fall pattern, vegetation cycles, atmospheric conditions and humidity conditions. Meteorological aspects and the hydrologic regime of the area along with the agricultural work schedule are important aspects when change detection analysis is performed [7]. This problem can be overcome by some atmospheric problem correction techniques such as atmospheric correction model and image to image normalization techniques. Special radiometric and geometric correction techniques are applied on the collected data which is further followed by Change Detection Techniques.

4. CHANGE DETECTION TECHNIQUES FOR LAND USE AND LAND COVER

Change detection is a phenomenon in which differences in the state of an object is observed at different intervals of time. The properly measured time and accuracy of change detection techniques can provide better understanding of relationships between the living and non-living things, optimal usage of resources and proper management of available resources. To achieve these goals we have integrated Geographic Information System with Remote Sensing.

The type of the change detection method implemented can profoundly affect the qualitatively and quantitative estimates of the disturbance [9].

4.1. Image Differencing Technique

It is a very simple change detection technique in which the pixel sample class is divided into change or no change classes. The general process for detecting the change in two dates in image differencing is extracting the change of the image of date 2 from the image of date 1 (e.g. image of date 1—image of date 2) [10]. In this technique, it is necessary to select thresholds for determining the changed area [11]. Image differencing is widely utilized for change detection in the geographical environment [11]. It has been used either as a single-band difference [12] or as a color composite of three bands [13]. This technique is used in the detection of Land use and Land cover change phenomenon.

4.2. Image Ratioing

Image ratioing is extracting the information between two or more different images by using the same bands of two or more images. Here we simply deal with the division of pixels of bands at different time intervals. For example dividing band 2 at t1 by band 2 at t2. This gives the change in the pixels and hence difference in two images can be calculated. The unchanged pixels has the same number for both the dates with a grey level. The image ratioing technique is useful for extracting vegetation cover information. The advantage of this technique is that the effect of shadows, the radiation change, image noise and the sun angle can be reduced [14]. However, there are two major disadvantages: it is difficult to select the threshold value, and the type of changes cannot be analyzed. It does not provide change direction [15].

4.3. Change Vector Analysis (CVA)

The Change Vector Analysis method overcomes the disadvantages of Image Ratioing method. It represents both- the direction and magnitude of the change. This method uses the Euclidean distance to formulate the change [16]. This technique, because of its qualities, was also used to examine inside and outside changes of the Chernobyl Nuclear Power Plant. It was able to differentiate several processes and phenomenon in the environment. This is also used to examine spruce-fire ecosystems, land use and land cover changes over oceans and seas.

4.4. Principle Component Analysis (PCA)

Principle component analysis, also referred to as Eigen-vector transformation, Hotelling transformation and Karhunen Loeve transformation in remote sensing, is a multivariate technique [17] that is used to reduce dataset dimensionality. It involves interpretation of simpler datasets. But this technique also requires a threshold value for interpretation and it gives an incomplete matrix. It is scene dependent technique which makes it difficult to label the dates and change type differentiation is not possible. It has an advantage of data redundancy reduction and it emphasizes different information in the derived components. [18] Compared four techniques, including image differencing, image ratioing, image regression and PCA, from a mathematical perspective. He recognized that standardized PCA achieved the best performance for change detection. Standardized PCA is better than un-standardized PCA for change detection because, if the images subjected to PCA are not measured in the same scale, the correlation matrix normalizes the data onto the same scale [19].

4.5. Chi-Square Transformation

The single change image is produced by considering multi bands of the image. This technique is also known as Pearson's Chi-Square technique. The chi-square transformation change detection technique was introduced by Ridd and Liu [18]. The current formula for the change detection is given by [18]

$$Y=(X-M)^T\Sigma^{-1}(X-M)$$

Where

Y= digital value of changed image

X= vector of difference of six values between the two dates (old and new dates)

M= mean of the residuals of each band
T= Transverse of the matrix
$\sum^{-1}$ = Inverse covariance matrix

4.6. Artificial Neural Networks (ANN)

Artificial Neural Networks represents statistical learning models and uses approximate functions. This is inspired by Biological Neural Networks. They are the system of interconnected neurons having weights and are capable of learning things. The properties of ANN which makes them to use in this field is its adaptive learning behavior, self-organizing structure, its real time operation and fault tolerance through redundant information coding. The architecture of ANN usually consists of three types of layers- an input layer, hidden layer and an output layer. In the input layer, the neurons can be the multispectral reflectance values for each pixel with their texture, e.g. elevation, slope and aspect. In the hidden layers, the use of neurons enables the simulation of nonlinear patterns in the input data. And lastly, in the output layer, the neuron represents a single thematic map for each individual land cover class e.g. agricultural or urban [20].ANN is used to detect the changes in urban areas, land use and land cover changes with the integration of Remote Sensing and Geographic Information System. Unsupervised classification was performed to determine the change in eelgrass meadows with Landsat TM data by Macleod and Congalton [21]. The back-propagation algorithms are used to detect Vegetation changes.

4.7. Hybrid Change Detection

This detection technique uses the combination of change detection techniques so that the advantages of different techniques can be combined to get a proper output set. It combines several techniques like CVA with PCA and Image Rationing with CVA. The procedural hybrid change detection technique uses different procedures on detection techniques. Another technique is based on the results which analyze the output after combining several change detection techniques. Hybrid change detection, combining the advantages of supervised and unsupervised classification, was used to derive a land cover map from three Landsat Thematic Mapper Plus (ETM+) images from the year 2000 in three Eastern Europe countries (Slovakia, Poland and Ukraine). The results were more accurate than using individual techniques [22].

4.8. Geographic Information System (GIS)

The techniques discussed so far are all based on pixel by pixel change detection. So to increase the accuracy of the result the integration of GIS and Remote Sensing is required .Hence the collateral information like Digital Elevation Model (DEM) can be used as analysis purpose. It helps in detection of changes more clearly as compared to other techniques. However, using different source data with different formats and accuracies may affect the change detection results [15]. The remotely sensed software and supervised classification algorithms are used to detect the changes. It also provides screen digitizing of the satellite images for the analysis purpose.

5. Change Detection Techniques Based on High Resolution Remote Sensing Data

5.1. Pixel Based Change Detection Technique (Traditional Approach)

The pixel is the basic unit of image analysis. During the change detection analysis spectral characteristics of each pixels is measured and detected without considering the spatial context [23]. There are several methods through which pixel based change detection can be implemented.

Some of them are Machine Learning, Spectral Mixture Analysis, Fuzzy change detection using fuzzy sets and fuzzy membership functions and Multi sensor data fusion. This method requires a Threshold Value. But identifying the threshold value is not an easy task especially when we are using unsupervised techniques as they lack ground truth points. When we are applying pixel based detection techniques on forest areas to find the crown covers we need to find crown cover boundaries on which detection algorithms are applied, again which is not an easy task.

5.2. Object Based Change Detection Technique

As an alternative to traditional approaches, object-based classification was introduced and has been widely used to solve the problems associated with the high spatial resolution domain which is not easy by pixel based methods [24]. In the object based classification the image objects are extracted then classification through supervised or unsupervised algorithms are applied. The object based image analysis has been used in the direction of reducing the effects of higher spectral variability, reduce the effect of geo-referencing and acquisition characteristics [23]. This method allows the segmentation and extraction of features from VHR data and also facilitates the integration of raster based processing and vector based GIS [25]. The segmentation process divides an image into homogeneous objects which are spectrally similar and spatially adjacent [26].

The best classification principles of “homogeneity within objects and heterogeneity among objects” is the important factor in the decision process of the best scale for segmentation [27].The segmentation algorithms affect the geometry of the results object which need appropriate solution to keep the relation of the extracted objects for two different times for detecting changes [23]. Also, there are not strongly reliable methods for accuracy assessment of object based detection methods yet. Most of the accuracy evaluation based on pixel based methods [28].

6. RESULTS AND CONCLUSION

Table 1 Comparison between different change detection Techniques

Change Detection Technique	Provides Change Direction	Selection of Threshold	Selection of Training sets	Provides change Matrix
1.Image Differencing	No	Yes	No	No
2.Image Rationing	No	Yes	No	No
3.Change Vector Analysis(CVA)	Yes	Yes	No	No
4.Chi-Square	No	Yes	No	No
5.Hybrid change Detection	No	Yes	No	No
6.Artificial Neural Networks(ANN)	Yes	No	Yes	Yes
7.GIS	Yes	No	No	Yes

The integration of GIS with Remote can be used to examine the impact of GIS on individuals and society as a whole and re-examines the themes with incorporation of most recent cognitive and Information Science. The application domain of remote sensing is from a base layer for GIS to the development of thematic datasets, obtaining and extracting data from imagery and generation of unique spatial datasets. Therefore it requires a need of data collection, methods and techniques through which processing and understanding of the change can be faster, reliable and economical. Change detection is a phenomenon in which differences in the state of an object is observed at different intervals of time. We humans have to understand the change. And this is possible only if we have an interface through which we can capture the changes. Hence Remote Sensing and GIS plays an important role in the Climate change Detection, Evaluation detection, Understanding our environment in a better way and hence survival on Earth.

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