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Mapping of Geological Structures using Aerial Photography

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Abstract—*Rapid growth in data acquisition technologies through drones, have led to advances and interests in collecting high-resolution images of geological fields. Being advantageous in capturing high volume of data in short flights, a number of challenges have to overcome for efficient analysis of this data, especially while data acquisition, image interpretation and processing.*

We introduce a method that allows effective mapping of geological fields using photogrammetric data of surfaces, drainage area, water bodies etc, which will be captured by airborne vehicles like UAVs, we are not taking satellite images because of problems in adequate resolution, time when it is captured may be 1 yr back, availability problem, difficult to capture exact image, then night vision etc. This method includes advanced automated image interpretation technology and human data interaction to model structures and. First Geological structures will be detected from the primary photographic dataset and the equivalent three dimensional structures would then be identified by digital elevation model. We can calculate dip and its direction by using the above information.

The structural map will be generated by adopting a specified methodology starting from choosing the appropriate camera, camera's mounting system, UAVs design (based on the area and application), Challenge in air borne systems like Errors in image orientation, payload problem, mosaicing and geo referencing and registering of different images to applying DEM.

The paper shows the potential of using our method for accurate and efficient modeling of geological structures, capture particularly from remote, of inaccessible and hazardous sites.

Keywords: *Mapping; Photogrammetric data analysis; Digital elevation model*

1. INTRODUCTION

The most fundamental properties of geological structures are location, surface geometry and orientation because these are the key features of techniques used in the research work in geosciences such as 2D cross section construction, 3D modeling of geological structures etc. Basically geosciences starts the journey from structural features, these are important for a vast range of geo research, mineral exploration industries, industries related to geothermal energy and ground water. Possibly the geological map is the most elemental dataset, used to get information on geological structures. Length and area of interested structure, its location, geometry, orientation, dip and strike are some relevant information that we can extract out from structural maps. In order to obtain the highest resolution data, traditional field techniques include interpretations from photo mosaics or grid mapping but a lot of errors occurred in such techniques. Also the researchers had to use less resolution images, remotely captured by satellites. As those images are not having a good resolution, that may let it difficult to extract out the information.

With recent advances in aerial data acquisition technologies from aircraft and UAVs (Harwin and Lucieer, 2012 and Turner et al., 2012), it is now possible to capture high-resolution rock surface images and analyze geological structures within those datasets digitally. Very large digital datasets can be collected rapidly, covering significant surface areas with centimeter-scale resolution in a matter of minutes. (Yathunanthan Vasuki, 2014).

Photogrammetric is a technique that captures 3D information of features from two or more photographs of the same object, obtained from different angles (Donovan and Lebaron, 2009, Haneberg, 2008 and Linder, 2009). In particular, structure from motion (SfM), is a photogrammetric technique, where the camera positions and orientation are solved automatically, in contrast to conventional photogrammetric where a priori knowledge of these parameters is required (Snavely et al., 2007). SfM uses overlapping photos to construct 3D point clouds, from which it is relatively, straight-forward to calculate surface models such as wireframes or digital elevation models (DEMs) and finally generate orthorectified photo mosaics or textured surfaces. With the advent of this technique it is now important to develop methods to analyze the resulting data rapidly and effectively **(Yathunanthan Vasuki, 2014).**

A lot of study has been done by many researchers like **Kottenstette (2005)** to demonstrate the application of photogrammetric methods to map the locations of geological joints. **Ferrero et al. (2009)** judged the location, geometry, orientations of geological features derived from UAVs survey with the field survey. Sirovision, ShapeMetrix3D and 3DM Analyst are some software used to calculate the orientation of discontinuities.

Visual interpretation manually is really a very tedious task to indulge in and the most basic problem that we encounter during manual interpretation is that its efficiency depends upon the experience of the researcher, even the same person will not give the same result if asked for again interpreting.

Artificial intelligence is an attractive as well as active area of research in computer vision, including applications such as crowd detection, road extraction, number of vehicles passing through a cross section etc. Image analysis techniques provide an effective and fast method of lineament detection and these techniques can extract lineaments which are difficult to recognise using the human eye alone (Wang and Howarth, 1990). The main advantage of automated or semi-automated lineament detection is speed.

Data acquisition

Technically the data, collected will put for correction and ultimately processed with adequate techniques. Data acquisition will be accomplished by using camera mounted on UAVs.

Airborne system

For this we can design a quadcopter and a fixed wing which can carry around 1 kg of weight up to a height of several meters. Quad copter would be made by using 1000kv rating BLDC motors, Simonk firmware ESCs or electronic speed controller, dc battery, kk 2.1 onboard flight control board and 10 *4.5 propellers And the other model can be a four channel fixed wing having 18cm chord and wing span of 80 cm.

Challenges in air borne system are

1. Errors in image orientation.
2. payload problem

Error correction will be discussed later and ***pay load*** problem can be easily overcome by considering different motors and propeller combination but high power battery (heavy and costly) required with aftermath of very high power motors, so it is very crucial to have a good pond of knowledge and practice of aircraft flying so that it would become easy to decide the combination of motor and propellers.

For this we need a UAV that is equipped with the current and advanced technologies such as onboard GPS, fiber optics gyro, autopilot chipset, electronic speed controller, wireless antenna, camera mount, high resolution digital camera, high end transmitter and inertial navigation system (Mikropilot).

The images are taken autonomously by UAV based on flight path which would be programmed in flight mission control software.

Flight path will be decided in flight mission control software using different waypoints. However it is little bit different from the actual one that would be recorded after the flight path. Pre-flight planning is a must in photogrammetric work because it will reflect the quality of the end products.

2. CAMERA MOUNT SYSTEM

The very crucial thing before taking the photographs is the orientation of camera that depends upon the mounting system that we are using. Camera mounts serve for attaching one or more cameras or other sensors to a platform and operating them. The most basic function is triggering the camera, usually with remote controlled micro-servos and additional functions may include pan and tilt orientation, remote image capture, and control of ancillary devices such as GPS, altimeter, or video eye.

3. IMAGE PRE PROCESSING

It is usually necessary to preprocess remotely sensed data and remove geometric distortion so that individual picture elements (pixels) are in their proper planimetric (x, y) map locations. This allows the derived information to be related to other thematic information in geographic information systems (GIS) or spatial decision support systems (SDSS). Geometrically corrected imagery can be used to extract accurate distance, polygon area, and direction (bearing) information.

3.1 Internal and External Geometric Error

Remotely sensed imagery typically exhibits internal and external geometric error.

3.2 Internal Geometric Error

Internal geometric errors are introduced by the remote sensing system itself or in combination with Earth rotation or curvature characteristics. These distortions are corrected using pre-launch or in-flight platform ephemeris (i.e., information about the geometric characteristics of the sensor system and the Earth at the time of data acquisition). Geometric distortions in imagery that can sometimes be corrected through analysis of sensor characteristics and ephemeris data include: variation in ground resolution cell size, relief displacement, tangential scale distortion.

3.3 External Geometric Error

External geometric errors are usually introduced by phenomena that vary in nature through space and time. The most important external variables that can cause geometric error in remote sensor data are random movements by the aircraft (or spacecraft) at the exact time of data collection, which usually involve: change in attitude and altitude.

Quality remote sensing systems often have gyro-stabilization equipment that isolates the sensor system from the roll and pitch movements of the aircraft. Systems without stabilization equipment introduce some geometric error into the remote sensing dataset through variations in roll, pitch, and yaw that can only be corrected using ground control points.

4. IMAGE MOSAICKING

Steps should be followed to mosaic the images

1. Individual images should be rectified to the same map projection and datum. Ideally, rectification of the *n* images is performed using the same intensity interpolation re sampling logic and pixel size.
2. Assume a base image one image amongst the images to be mosaicked, image next to the base image must overlap the base image to some extent.
3. Extract out the histogram of the overlapped area of base image. Then use histogram matching algorithm by applying the histogram of next image, by this both images will have the same gray scale characteristics.
4. Sometimes, due to significant differences in brightness of both scenes. Unfortunately, this can result in noticeable seams in the final mosaic. Therefore, it is common to blend the seams between mosaicked images using feathering. (By Introductory Digital Image Processing (3rd Edition) [John R Jensen])

5. IMAGE PROCESSING

Image processing is the terminology used to extract out the information from the image using various programs, algorithms and software.

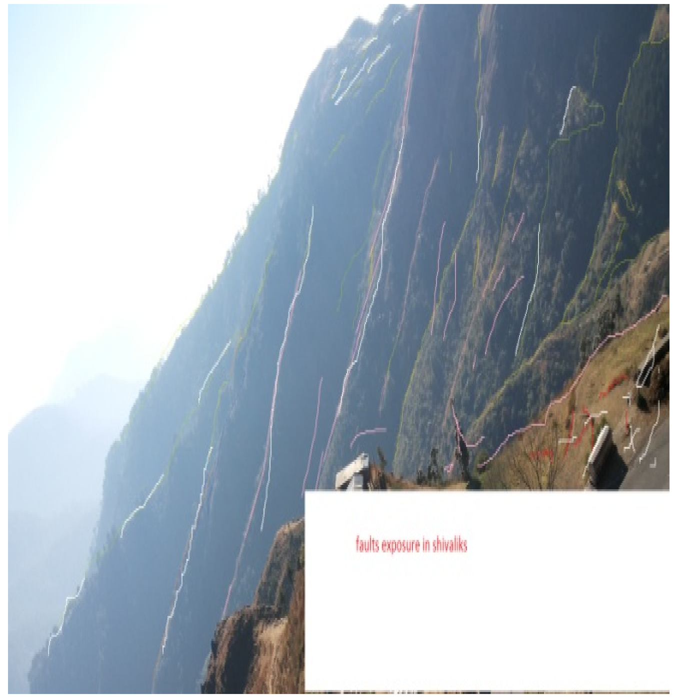
For geological rock features we used algorithms described by **Yathunanthan Vasuki, 2014,** in his paper on semi automatic mapping of geological structures, such as edge detection (sobel, prewitt, canny method), hough transformation, phase congruency (kovesi).

When the performance of these widely used spatial domain edge detection methods was compared, the results showed that the Canny (1986) method performs well and is able to detect strong and weak edges (Juneja and Sandhu, 2009, Maini and Aggarwal, 2009 and Marghany et al., 2006).

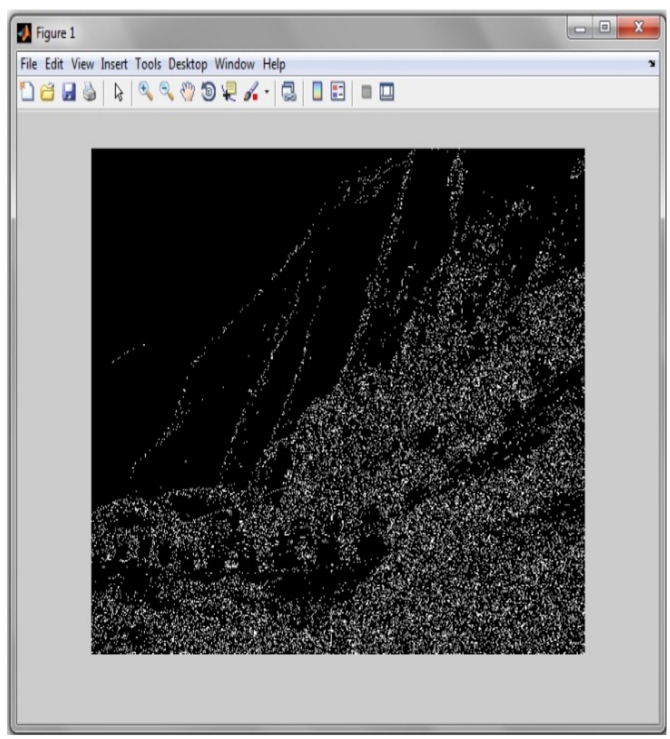
Phase symmetry (kovesi, 1997) is an algorithm already used in geology and geophysics to detect regions of magnetic discontinuity (holden et al, 2008). This method is invariant to local signal strength. .

The phase congruency method (Kovesi, 1999) is a edge detection method that detects features by identifying points where the Fourier components are maximally in phase. Phase congruency provides a measure that is invariant to the magnitude of the signal. Phase congruency can be used to detect edges from the images. This algorithm is detailed in Kovesi, 1999, Kovesi, 2002 and Kovesi, 2003 and a MATLAB implementation is available in Kovesi (2000).

Geologic features are identified by applying all the above discussed algorithms, their MATLAB codes are freely available on internet.



Manual detection of geological features in early shivaliks



Feature Detection of shivalik hills near mussoorie using edge detection

Ripple marks seen in high resolution photo by quad copter

Automated 3D structure analysis

5.1 3D structure detection

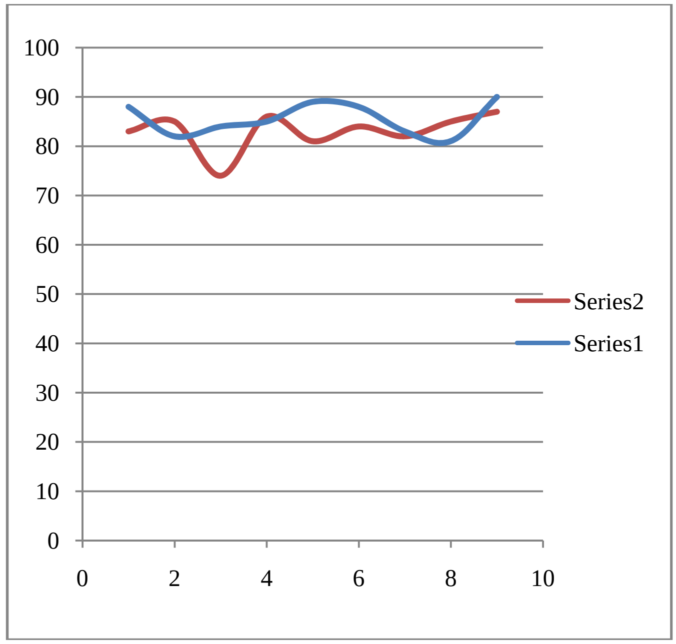
Once the structures are identified in the 2D images the 2D feature points *X*2*d*, *Y*2*d* (pixel coordinates) are computed and their corresponding 3D feature coordinates (*X*3*d*, *Y*3*d*) are calculated. The *Z* coordinate of the feature point, *Z*3*d* can be calculated from the DEM using bilinear interpolation. This approach requires the 2D images to be orthorectified. Note that the output of the bundle adjustment process provides the camera location and calibration parameters. If the images are not orthorectified, these can be used to project a viewing ray corresponding to a feature location in the 2D image into the 3D surface. The intersections with the 3D surface will give the 3D location of the feature points.

6. ORIENTATION CALCULATION

After getting the 3D feature points its time to find out the dip and dip direction for this we need to find out the best fitted planes. The data for the same can be obtained from the 3D point cloud obtained in DEM.

The best fit plane will be having an equation of a plane and by knowing its coefficients the dip and its direction can be calculated.

Comparison between field surveyed data and photogrammetric data calculated in 9 different locations of rishikesh, Himalayas.



x axis represents 9 locations and on y axis dip angles are represented.

Series1 is photogrammetric data.

Series 2 is field data.

7. CONCLUSION

This paper suggests a good and efficient method for extracting the information from images and helps in exploration process of geological fields which can later be useful in oil and gas industries, mining industries and other earth science related organizations.

The data we get from manual interpretation has been compared with the photogrammetric data and by doing the error analysis it is found that the automated system if improved a little can give better efficiency than the manual interpretation.

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