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A Novel Method for Feature Extraction and Classification for an Aerial Image and LiDAR Data with Genetic Algorithm

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Abstract - Airborne Light Detection and Ranging (LiDAR) provides accurate height information for objects on the earth, which makes LiDAR become more and more popular in terrain and land surveying. In particular, LiDAR data offer vital and significant features for land-cover classification which is an important task in many application domains. Aerial photos with LiDAR data were processed with genetic algorithms not only for feature extraction but also for orthographical image. DSM provided by LiDAR reduced the amount of GCPs needed for the regular processing, thus the reason both efficiency and accuracy are highly improved. LiDAR is an acronym for Light Detection and Ranging, which is typically defined as an integration of three technologies into a single system, which is capable of acquiring a data to produce accurate Digital Elevation Models.

Keywords - GA, LiDAR, Feature Extraction.

I. INTRODUCTION

The use of LiDAR data for terrain models and topographic mappings have gained wide attention in recent years as it contains height data on the Earth's surface.

The three technologies are Lasers, Global Positioning System (GPS) and Inertial Navigation System (INS). These technologies combine to provide positioning of foot prints of laser beam that hits an object with a high degree of accuracy. These technologies are used by NOAA and NASA scientists to document topographic changes.

The need for precise Digital Terrain Model (DTM) in producing the stereo images have been a time and cost consuming tasks for all the image processing work [1]. Beside the existing data base, one can only create the matching DTM from stereo pairs of incoming images. For that, large amount of ground control points (GCPs) are needed, so is the stereo images that fit within the pre-defined conditions. Three dimensional virtual reality (3D VR) is one of the particular usage that require much dense DTM grid than others. LiDAR could provide both the DTM and DSM at one aerial data gathering, point cloud data thus convert into DTM grid within error of 15 cm. Genetic algorithms could search the global domain, and also reject the candidates with

large bias automatically. With it, one can match the DSM to image with much less human interactive.

Once the orthographic image was processed, GAs was brought into for unsupervised feature extraction.

II. SYSTEM DESIGN:

Fig. 2.1: Block Diagram

2.1 DEM Conversion:

Digital Elevation Models are data files that contain the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth. The

intervals between each of the grid points will always be referenced to some geographical coordinate system. This is usually either latitude-longitude or UTM (Universal Transverse Mercator) coordinate systems. The closer together the grid points are located, the more detailed the information will be in the file. The details of the peaks and valleys in the terrain will be better modeled with small grid spacing than when the grid intervals are very large. Elevations other than at the specific grid point locations are not contained in the file. As a result peak points and valley points not coincident with the grid will not be recorded in the file.

- The term digital elevation model or DEM is frequently used to refer to any digital representation of a topographic surface.
- However, most often it is used to refer specifically to a raster or regular grid of spot heights.
- Digital terrain model or DTM may actually be a more generic term for any digital representation of a topographic surface, but it is not so widely used.
- The DEM is the simplest form of digital representation of topography and the most common.
- A variety of DEMs are available, including coverage of much of the US from the US Geological Survey.
- The resolution, or the distance between adjacent grid points, is a critical parameter.
- The best resolution commonly available is 30 m, with a vertical resolution of 1 m coverages of the entire globe, including the ocean floor, can be obtained at various resolutions.

2.2 Run-Length Coding

Data files frequently contain the same character repeated many times in a row. For example, text files use multiple spaces to separate sentences, indent paragraphs, format tables & charts, etc. Digitized signals can also have runs of the same value, indicating that the signal is not changing. For instance, an image of the nighttime sky would contain long runs of the character or characters representing the black background. Likewise, digitized music might have a long run of zeros between songs. Run-length encoding is a simple method of compressing these types of files.

A good example of a generalized run-length scheme is Pack Bits, created for Macintosh users. Each byte (eight bits) from the input file is replaced by nine bits in the compressed file. The added ninth bit is interpreted as

the sign of the number. That is, each character read from the input file is between 0 to 255, while each character written to the encoded file is between -255 and 255. To understand how this is used, consider the input file: 1,2,3,4,2,2,2,2,4, and the compressed file generated by the Pack Bits algorithm: 1,2,3,4,2,-3,4. The compression program simply transfers each number from the input file to the compressed file, with the exception of the run: 2,2,2,2. This is represented in the compressed file by the two numbers: 2,-3. The first number ("2") indicates what character the run consists of. The second number ("-3") indicates the number of characters in the run, found by taking the absolute value and adding one. For instance, 4,-2 means 4, 4, 4; 21,-4 means 21, 21,21,21, etc.

2.3 Feature Extraction

2.3.1 Wavelet Transform

The frequency contents of signals are very important, transforms are usually used. The earliest well known transform is Fourier transform which is a mathematical technique for transforming our view of the signal from time domain to frequency domain. Fourier transform breaks down the signal constituents into sinusoids of different frequencies. However, Fourier transform comes with serious shortage that is the loss of time information which means it is impossible to tell when a particular event takes place. This shortage vanishes with using wavelet transform. A shifted version of the original signal is called mother wavelet which it is a wave form effectively a limited duration and its average value is zero. The most well-known wavelets are Haar. Figure 2.2 depicts some types of these wavelets.

2.3.2 1-D Discrete Wavelet Transform

The CWT calculates coefficients at every scale which leads to need much time and awful lot amount of data. If scales and positions are selected based on powers of two, analysis will be much more efficient and accurate. This type of selection is called dyadic scales and positions. This analysis can be produced from the Discrete Wavelet Transform (DWT). DWT is used to decompose (analyze) the signal into approximation and detail called coefficients. Approximation coefficients represent the high scale (low frequency) components of the signal as if it is a low pass filter. Detail coefficients represent the low scale (high frequency) components of the signal as if it is a high pass filter. Given a signal S of size N , down sampling the approximation coefficients (cA) is given by $N/2$ and the detail coefficients (cD) is given by $N/2$ (Fig. 2.3).

Fig. 2.2

Fig. 2.3

2.3.3 2-D Discrete Wavelet Transform

Discrete Wavelet Transform (DWT) is not only applied to 1-D signals, but also applied to two dimensional matrices applied images. Each element in the matrix represents the intensity of grey color in the image. The computation of the wavelet transform of image is applied as a successive convolution by a filter of row/column followed by a column/row the results of DWT on images are four coefficients matrices.

Given image $f(x, y)$, the 2-D wavelet analysis operation consists of filtering and down-sampling horizontally using a 1-D low pass filter L and a high pass filter to each row in the image $f(x, y)$, and produces the coefficient matrices $f_L(x, y)$ and $f_H(x, y)$. Vertically, filtering and down-sampling follow using the low pass and high pass filters L and H to each column in $f_L(x, y)$ and $f_H(x, y)$. This produces 4 sub-images $f_{LL}(x, y)$, $f_{LH}(x, y)$, $f_{HL}(x, y)$ and $f_{HH}(x, y)$ for one level of decomposition. $f_{LL}(x, y)$ is a smooth sub-image, which represents the approximation of the image. $f_{LH}(x, y)$, $f_{HL}(x, y)$, and $f_{HH}(x, y)$ are detail sub-images which represent the horizontal, vertical and

diagonal directions of the image respectively. As mentioned before, DWT can be applied again to the approximation $f_{LL}(x, y)$ where the resulted coefficients matrix of approximation and details of DWT determined by the level k of decomposition using the relation $3k+1$. Below figures show the first and third level concepts of DWT for image $f(x, y)$.

III. EDGE DETECTION

Edges are pixels where the intensity of an image function changes abruptly. Edge detectors are collection of local image pre-processing methods used to locate changes in the brightness function. An image function depends on two variables co-ordinates in the image plane. Operators describing edges are expressed by partial derivatives. Change of the image function can be described by a gradient that points in the direction of the largest growth of the image function.

3.1 Segmentation

Image segmentation is an important technology for image processing. There are many applications whether on synthesis of the objects or computer graphic images require precise segmentation. With the consideration of the characteristics of each object composing images in

MPEG4, object-based segmentation cannot be ignored. Now a day's sports programs are among the most popular programs, and there is no doubt that viewers' interest is concentrated on the athletes. Therefore, demand for image segmentation of sport scenes is very high in terms of both visual compression and image handling using extracted athletes. In this project, there is an introduction of basic idea about color information and edge extraction to achieve the image segmentation. The color information helps obtain the texture information of the target image while the edge extraction detects the boundary of the target image. By combining these, the target image can be correctly segmented and represent. Besides, because color information and edge extraction can use basic image processing methods, they can not only demonstrate what textbook claims but also make us realize their function works. We expect that we can extract most part of the target.

The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic(s).

IV. GENETIC ALGORITHM

4.1 Decision making

The decision-making stage determines the probability of match between subject and reference image based on comparison of features extracted from both images.

4.2 Matching Algorithm

The genetic algorithm for the stereo correspondence works as follows. A population of images is randomly produced so that the local stereo constraints are satisfied. From a current population and after evaluation of each image, the population is reproduced by selecting particular image with a selection probability proportional to the fitness value. Crossover and mutation operations are then performed to produce a new generation of chromosomes. To obtain the new generation, we use deterministic and stochastic selections. Deterministic selection, which uses the elitist strategy, represents 10% of the size of the population. The algorithm is iterated until a pre-specified number of generations are reached. Once the evolution process is achieved, the optimal selection, which corresponds to the minimum value of the fitness, gives the pairs of matched edge points of an image.

V. MERITS & DE-MERITS

5.1 Merits

Within the last few years or so, there has been a trend among a handful of aerial LiDAR service providers to commoditize the acquisition and processing of LiDAR data. Unfortunately for the customers and the industry in general, nothing could be further from the truth.

We found the combination of GA and LiDAR could reduce the pre-processing tasks for the 3D VR tremendously.

LiDAR automated feature extraction tools can support assessment of the consequences of natural disasters, industrial accidents, and terrorist incidents. A finished urban model can be used in any number of applications including personal navigation devices, urban planning and emergency response.

Operation 'locally' and day or night.

More reliable DTM because of high point density Fast data-to-information processing.

5.2 De-Merits

The systems thus had limitations for covering wide areas. The range resolution and accuracy of the Lidar system are within 1 cm and 15 cm, respectively. The growing demand for feature extraction based on individual blocks.

The ability to detect a return signal from targets with weak reflective signatures and from targets at a great distance is a function of the laser power.

Early systems simply shot the laser downward, normal to the aircraft in a profile along the flight path.

Problems with data collection involving water surfaces (even very shallow water).

Cannot distinguish break lines (manual processing required).

Erroneous reflections off sides of buildings, mid canopy points, etc.

Limited cartographic license afforded with shape definition of features (eg. buildings).

High equipment cost; project cost is relatively expensive.

VI. APPLICATIONS

- Flood risk mapping.
- Oil & gas exploration surveys.

- Property assessment.
- Airport Exclusion zones.
- Rectification of Satellite Imagery.

VII. SIMULATION RESULTS

Fig. 7.1: Editor Window

Fig. 7.2 : GUI Window

The Fig 7.2 shows the GUI (Graphical User Interface) with the following push buttons.

Browse - It selects the Original Image.

DEM Conversion - It is a data file that contains the elevation of the terrain over a specified area, usually at a fixed grid interval over the surface of the earth.

Run Length Encoding - The goal is to reduce the amount of data needed to be stored or transmitted.

Feature Extraction - The purpose of feature extraction technique in image processing is to represent the image in its compact and unique form of single values or matrix vector.

Classification - It classifies the image using clustering techniques.

Load DSM Image (LiDAR Data) - It compares the classified image and DSM image.

Genetic Algorithm - Genetic Algorithms are adaptive heuristic search algorithm, basic concept of GA is designed to simulate processes in natural system necessary for evolution.

CLOSE - To close the GUI.

Fig. 7.3: GUI Window with original image.

The Fig 7.3 Shows the GUI once the Browse pushbutton is pressed, then an image has to be selected which is the original image. Here "SSIT Tumkur. Jpg" (746x512) image is selected as the original image and it is resized to 256x256.

Fig. 7.4: GUI Window with DEM image.

The Fig 7.4 Shows the GUI once the DEM conversion pushbutton is pressed. Here the DEM image is displayed showing the size of the image (256x256).

Fig. 7.5 : GUI Window with Run Length Decoded Output.

The Fig 7.5 Shows the GUI once the Run Length Encoding pushbutton is pressed. Here the Run Length Decoded output image is displayed.

Fig. 7.6 : GUI Window with Feature Extracted Output.

The Fig 7.6 Shows the GUI once the Feature Extraction pushbutton is pressed. Here the Feature Extracted output image is displayed by performing DWT with Haar Transformation.

Fig. 7.7 : GUI Window with Feature Extracted Output.

Fig. 7.8 : GUI Window with Classified Output.

The Fig 7.8 Shows the GUI once the Classification pushbutton is pressed. Here the classified and segmented output image is displayed by using Clustering technique.

Fig. 7.9 : GUI Window with DSM image.

The Fig 7.9 Shows the GUI once the Load DSM image pushbutton is pressed. Here the classified and segmented output image is compared with DSM image for the next step.

Fig. 7.10 : GUI Window with Genetic Algorithm Results

The Fig 7.10 Shows the GUI once the Genetic Algorithm pushbutton is pressed. Taking one point as reference, different points are joined with reference point is analyzed for finding the shortest path to show the best solution history.

VIII. CONCLUSION

1. The main goal of this paper is to reduce the complexity of pattern recognition and increase the overall accuracy of this problem.
2. This concept has been implemented in MATLAB7.6 version

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