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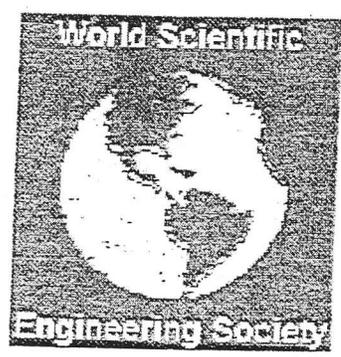
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A TWO PHASE DIGITAL ORTHO PHOTO MOSAICKING SYSTEM*

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Abstract

Digital orthophotographs is a geo-referenced image prepared from a perspective photograph or other remotely sensed data in which the displacement within the image due to sensor orientation and terrain relief [6] has been removed. Digital orthophotos serve a variety of purposes from interim map to field references for earth science investigations and analysis. Digital orthophotos constitute an important element in land information systems (LIS) and geographical information systems (GIS) and other applications [3]. Analysis of a large area requires the creation of an image mosaic, which are composed of several digital orthophotos [1]. In an ideal situation, a perfect mosaic can be obtained by placing the adjacent images next to one another like in a jigsaw puzzle. In practice, geometric distortions, radiometric differences and overlapping areas interfere with the mosaicking process.

In this paper, an efficient technique to mosaic digital orthophotos is presented. This technique can be applied to mosaic any set of digital orthophotos and works without any human intervention. The process of mosaicking is done in two phases. In the first phase, the ASCII header records of all the digital orthophotos needed for the mosaic are read and the necessary data is stored. Using the stored data, a virtual mosaic space of all the digital orthophotos is generated. In the second phase,

the raw data of all the digital orthophotos are processed based on the coordinates in the virtual mosaic. Since the data in each orthophoto is approximately 150 MB, the mosaicked image will be very huge. Thus for efficient viewing the mosaicked image is divided into tiles.

In this approach, there is no need to manually match the coordinates of adjacent images, to determine the order of images in the mosaic as it is taken care of by the system. The problem of overlapping data is overcome by assigning a descending level of priority from left to right and from top to bottom. The technique described in this paper has been implemented in Java and has been applied already for the mosaicking of aerial photographs of Miami-Dade county of Florida.

Keywords

Mosaicking, Digital orthophotos, Tiling

Introduction

One of the most significant advances in spatial data technology is the automated processing of orthophotographs. What was once a slow process requiring extensive human assistance can now be accomplished better and faster by computers [5]. Since the processing is done with an aid of a computer, the orthophotos have to be in a digitized form. This new process brings spatially corrected images into the computers, where data can be used for a variety

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of applications. Mosaicking several image frames gives us one image frame covering a large area. This large frame can be useful for map making, map revision, for GIS development by providing information that can be used to allocate farm-land for certain crops, prevent soil erosion and water pollution. The data can also be used to locate and number permanent farm-field boundaries and to locate and identify various classes of wetlands [2].

Currently, mosaicking can be accomplished with commercially available software like ENVI and ERDAS. This software requires a human to input the coordinates of the overlapping points between sets of images. Thus, a small error could lead to repetitive data or loss of data.

In this paper, we propose an efficient technique by which the digital orthophotos can be mosaicked, tiled, stored in a database for retrieval. This paper completely automates the process of image mosaicking yielding a perfect mosaic.

2. Digital Orthophotos Structure and Format

The standard uncompressed DOQ format [4] contains four ASCII header records (metadata) followed by a series of 8-bit image data lines. The line length of DOQs varies from file to file. The header is affixed to the beginning of the image and is composed of strings of 79 characters followed by a new line character. The key word based ASCII header may vary according to the number of data entries. Optional specifications exist in the header format to allow expansion of the header to include additional information concerning future programs. The header records are structured as a series of four-header records. Each record has 400 bytes of ASCII text. The four header records contain a wide range of descriptive information about the image data, including file identification, the coordinate systems and datum upon which the digital orthophoto is cast. The normal orientation of the image data is by lines (rows) and samples (columns). Each line contains a series of pixels ordered from west to east. The lines are ordered from north to south. Radiometric image

brightness data that are stored as 256 gray levels is represented as integers in the range of 0-255. The standard DOQ format is either 3.75-minute quarter quadrangle or 7.5 minute quadrangle. The pixel values represent black and white, color-infrared or natural color image. In this paper, we are interested in the DOQ with 3.75-minute quarter quadrangle format only. Digital orthophoto quarter-quadrangles are formatted according to the North American Datum of 1983 (NAD 83). The coordinates are represented in meters according to the Universal Transverse Mercator (UTM) projection system. The 3.75-minute quarter quadrangle DOQ has a ground pixel distance of 1 meter. The geographic extent of the digital orthophoto is equivalent to 3.75-minutes of latitude and longitude, plus a minimum of 50 meters to a maximum of 300 meters of over-edge. This over-edge is sufficient to offer coverage to encompass the four primary and four secondary horizontal datum corner (tick) points. The over-edge is useful for edge matching and mosaicking of quadrangles by offering areas outside the primary area of interest, which facilitate tonal matching between images. It is also evident from the header data that

- the two right corner points overlap with the two left corner points of its right neighbor
- the two left corner points overlap with the two right corner points of its left neighbor
- the two top corner points overlap with the two lower corner points of its upper neighbor
- the two lower corner points overlap with the two top corner points of its lower neighbor

Every orthophoto is a rectangle, but may not necessarily be the same size as its adjoining neighbor. The four primary datum corners are imprinted on the image as four solid white crosses ($0 \leq \text{brightness values} < 256$) and the four secondary datum corners as four dashed white crosses ($0 \leq \text{brightness values} < 256$). It is important to note that the four primary tick points mostly do not form a rectangle. This applies to the secondary tick points too.

3. Algorithm Overview

The mosaic algorithm is based on the three major steps as described below:

A. Establishment of bounding boxes

In the first step of phase-I, the ASCII header file of each image is read and the coordinates of the four primary corners are obtained. From this information, an outer-bounding box, which is the smallest upright rectangle containing the four primary corner points is established. Since the data outside an image's primary datum corners can be found within the primary datum corners of its adjacent images, the establishment of a bounding box helps to eliminate repetitive processing. An inner bounding box, which is the largest upright rectangle enclosed by the four primary corners, is also computed. Since the inner bounding box is within the four primary corners, all the pixels within the inner bounding box are selected thus saving processing time.

B. Creating a virtual mosaic

This is the second step of the phase-I. Since the corner points of the images overlap in a fixed manner as described in section-2, a virtual mosaic is created based on this property of the primary corners. We start by assigning a virtual coordinate (0,0) to the top left primary corner of the top left image of the virtual mosaic. Then we calculate the virtual coordinate values of the primary corners of all other images. Once the images are virtually laid out in the mosaic, the coordinates of the corners of the virtual mosaic are obtained. This gives us an estimate of the area of the mosaicked image.

C. Mosaicking and Tiling

Once the virtual mosaic is created, the raw data in the digital orthophotos can be read to actually begin the process of mosaicking. The image data is read one line at a time. This line is called the scan line. All the pixels within the inner bounding box are within the coordinates of the four primary corners, so all these pixels are selected without examination. Similarly, all the pixels outside the outer bounding box are outside the coordinates of the four primary corners, so they are all rejected. The pixels between the outer and the inner bounding box are examined to see if they lie within the coordinates of the four primary corners. If so, the pixels are selected, else they are rejected. Thus, there are three categories of pixels to be examined.

The size of the data within the four primary corners is approximately 130 MB. To facilitate fast and random access to the image segments, the images are divided into tiles of 256 x 256 pixels as they are mosaicked. The process of tiling serves two purposes. Firstly, it enables easy viewing of the mosaicked images and secondly, it provides us the flexibility of viewing only the desired area of any image.

4. Implementation

The digital orthophotos of Miami-Dade County were obtained from the United States Geological Survey (USGS) in the form of CDs. Approximately, 69 digital orthophotos covering most of the southeast and northeast regions of Miami-Dade County were used. The header files and the image files are read/processed in two phases using a user-friendly interface. Since the image files are binary, the mosaicked and tiled images are stored as PPM (portable pixel map) format, which can then be viewed using commercial software like LView Pro. The tiled images are stored in a semantic database for efficient retrieval. The user interface and the process of mosaicking were done in Java. The purpose of using Java was to exploit platform independence and to provide web access. Since the orthophotos have a resolution of 1 meter per pixel, the orthophotos provides us with many details. To enable viewing a larger area with fewer details, data can be synthesized from the existing one-meter resolution tiles. The zoom-out data are efficiently generated as the digital orthophotos are mosaicked and are stored as tiles of the same size. This produces data necessary for only two levels of details. To obtain data for further zoom levels, a separate layer of tiles is generated for each additional level. Each layer gives a particular level of detail. The maximum number of layers that can be obtained is $\max(\lceil \log_2 m \rceil, \lceil \log_2 n \rceil)$, where m is the number of images per row in the virtual mosaic and n is the number of images per column in the virtual mosaic. The uppermost layer will have only one tile.

5. Conclusion

We have presented an algorithm for mosaicking spatial images. The algorithm

divides each scan line of an image into three linear segments according to the quadrilateral boundaries formed by the corner (tick) points. If the middle segment is a valid segment, only the pixels of this segment are accepted. This process of efficient selection of pixels speeds up processing time. In addition, any number of images can be mosaicked as there is no upper limit to the number of images that can be mosaicked. The virtual mosaic capability allows users to create a mosaic without creating large output files. From this virtual mosaic, smaller output files (tiles) are created to enable easy viewing of the data. In addition, the algorithm generates zoom-out data of several layers to facilitate the display large area with different resolutions. This application is limited to mosaicking digital orthophotos. A future enhancement of this project is to be able to mosaic images of either any single format or heterogeneous formats.

We have developed a system that allows a user to fly through distributed mosaicked spatial data in real time and deliver to the user's WWW browser in a smooth motion. Please see a demo at <http://hpdr.cs.fiu.edu>. At present, the demo allows flight over aerial photography data according to the user's choice of direction and resolution (zoom in/out) at run time.

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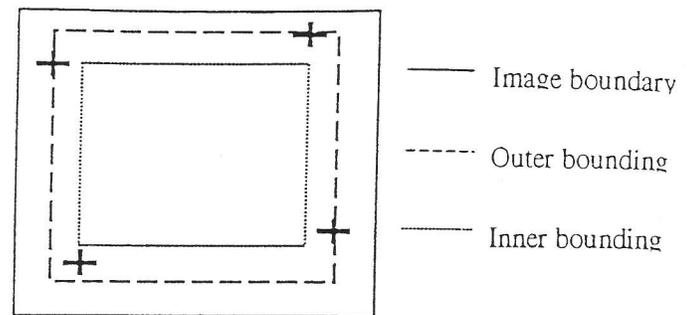


Figure 1. Image with the four tick points and bounding b

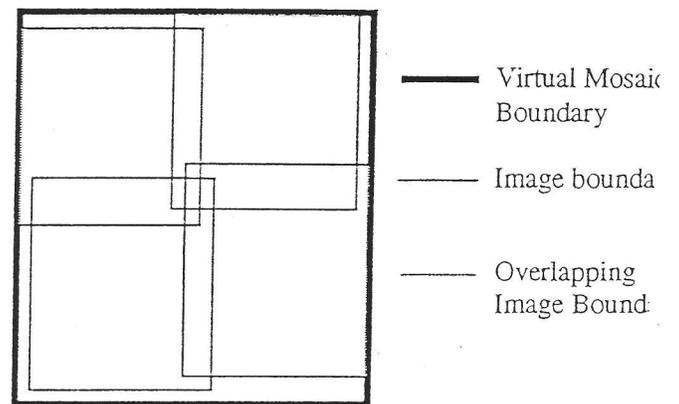


Figure 2. Virtual mosaic of four images

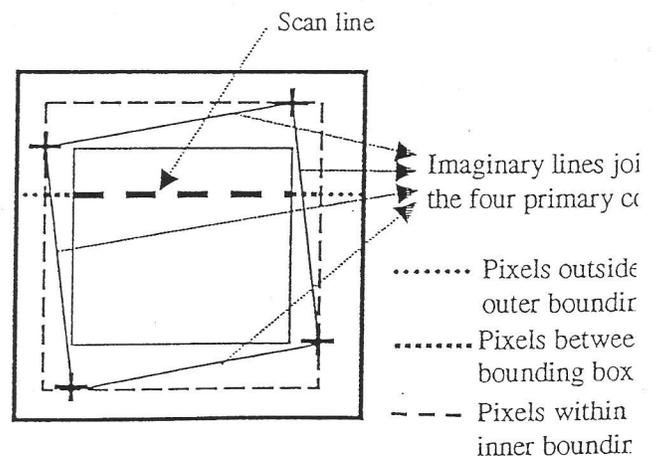


Figure 3. Scan line showing the three categories of pi