GEOSPATIAL OBJECT BASED MOSAICING OF HIGH-RESOLUTION THERMAL AIRBORNE IMAGERY (TABI 1800) TO IMPROVE ROOF SHAPE AND THERMAL STATISTICS

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ABSTRACT:

We describe a novel GEOBIA based mosaicing algorithm referred to as *Object-Based Mosaicing* (OBM) that joins thermal flight-lines around urban roof-objects rather than bisecting them with arbitrary mosaic joins. This technique results in (i) visually improved roof shapes within the scene, (ii) more accurate hot-spot detection, and (iii) more accurate thermal-based home energy models, as the data for each roof are from a single acquisition time. As part of the *Home Energy Assessment Technologies* (HEAT) project, this algorithm is evaluated on a two flight-line TABI-1800 mosaic (2 km x 7.5 km @ 1.0 m) which is part of a full (23 km x 35 km) City of Calgary, Alberta, Canada 36 flight line mosaic. We estimate that without applying OBM to the full scene, some 24,500[1] homes will be bisected within the vendor provided (pixel-based) mosaic.

1. INTRODUCTION

For large area High-spatial resolution (H-Res) urban mapping, thermal infrared (TIR) airborne imagery needs to be acquired in a number of flight-lines and the scenes need to be mosaiced together (Weng 2009; Hay et al, 2011). Traditional mosaicing algorithms join two or more images using superimposing methods. However, due to geometric and radiometric variations during different acquisition times, the same objects tend to have different spectral characteristics within and between flight-lines, resulting in reduced classification accuracies. In addition, arbitrarily joining flight-lines in an urban scene typically results in bisected roof tops as each portion of a roof (along a join) are acquired from different flight lines. In the case of thermal imagery, this results in roof-objects represented by temperatures from different times; which due to climatic variability, significantly affects related thermal statistics derived for each roof. As a part of the HEAT project (www.wasteheat.ca : login beta, pwd beta - Hay et al., 2011), a Geoweb decision-support service which allows residents to visualize the amount and location of waste heat leaving their homes and communities), a full City of Calgary thermal airborne mosaic (35 Km x 35 Km) covering 450,000+ homes was created by ITRES Research Ltd from 36 TABI-1800 (Thermal Airborne Broadband Image) flight lines, each 35 km long (at a 50 cm spatial resolution). This mosaic was automatically created using very precise in-flight GPS data, and traditional geocorrection methods. However, because it did not take roof-objects into consideration within the geocorrection process, an estimated 24,500 roofs may be bisected within the full mosaic.

In an effort to minimize this effect, we propose a GEOBIA solution referred to as *Object-Based Mosaicing* (OBM) that joins thermal flight-lines around roof-objects rather than bisecting them with arbitrarily defined mosaic join-lines.

2. STUDY AREA AND DATASET

Our study area is located in the southwest quadrant of The City of Calgary, Alberta Canada, and is represented by a two flight-line sample (2 km x 7.5 km @ 1.0 m) of TABI-1800 imagery acquired at night (00:00 to 04:30) on April 16, 2011 (Figure 1). These data represent a small portion of a full City of Calgary H-Res thermal data acquisition (previously described).

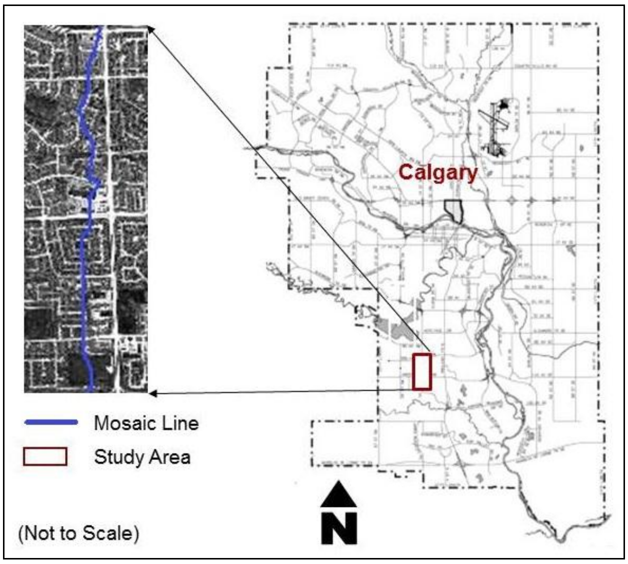


Fig 1. Location of the study area

This site comprises 3000+ residential buildings, the majority of which were built between 1961 and 1965 - suggesting that they are good candidates for potential energy saving renovations. The TABI-1800 is a recently developed (ITRES, 2011) airborne thermal sensor with a swath width of 1,800 pixels in the 3.7 - 4.8 micron spectral region, a thermal resolution of 0.05 °C, and

[1] Based on a conservative estimate of 20 roofs/km * 35 km/flight line * 35 flight line joins.

the ability to collect up to 175 km^2 per hour at 1.0 m spatial resolution. This is three to five times larger and faster than most other airborne TIR sensors (Hay et al., 2011). In an optimal data acquisition scenario, each TABI 1800 flight line is acquired with a 30% overlap with the adjacent flightlines; though this is seldom achieved over the entire dataset, due to wind and pilot error.

The entire dataset available for this research includes: (i) a TABI 1800 thermal mosaic (at a 1.0 m spatial resolution) for the full City of Calgary (23 km x 35 km), (ii) 36 corresponding TABI-1800 flight lines also at 1.0 m, and (iii) City of Calgary GIS (Vector) Cadastral layers including building outlines and roads.

3. METHODOLOGY

Object-Based Mosaicing (OBM)

In this section we describe the *Object-Based Mosaicing* (OBM) pseudo code, which is developed to incorporate only *whole roofs* within the mosaic process (Figure 2). In all cases we assume that each flight line has previously been geometrically corrected by the data provider with a spatial error of ±2 pixels (or less).

OBM Pseudo Code

- In the case where city GIS cadastral polygons exist, each flight needs to be geometrically corrected to the corresponding GIS roof polygons.
- In the case where only thermal data exists, object-based feature detection will be applied to each flight line (separately) to extract roof-objects (i.e., polygons).
- A suitable sized buffer needs to be generated around each roof-object (e.g., 2–3 times the images reported geometric correction error) to compensate for (the majority of) unresolved local geometric errors between flight lines.
- The overlap between two adjacent flight lines is defined, from which a *center-line* will be defined (yellow line in Figure 2).
- The buffered roofs that are bisected by this new center-line will be identified.
- Based on the proximity of each bifurcated roof to the center of its flight line (so as to reduce radial displacement effects) a new mosaic line (red line in Figure 2), will be joined around the defined roof buffers (blue rectangles in Figure 2) and used to mosaic adjacent datasets together.

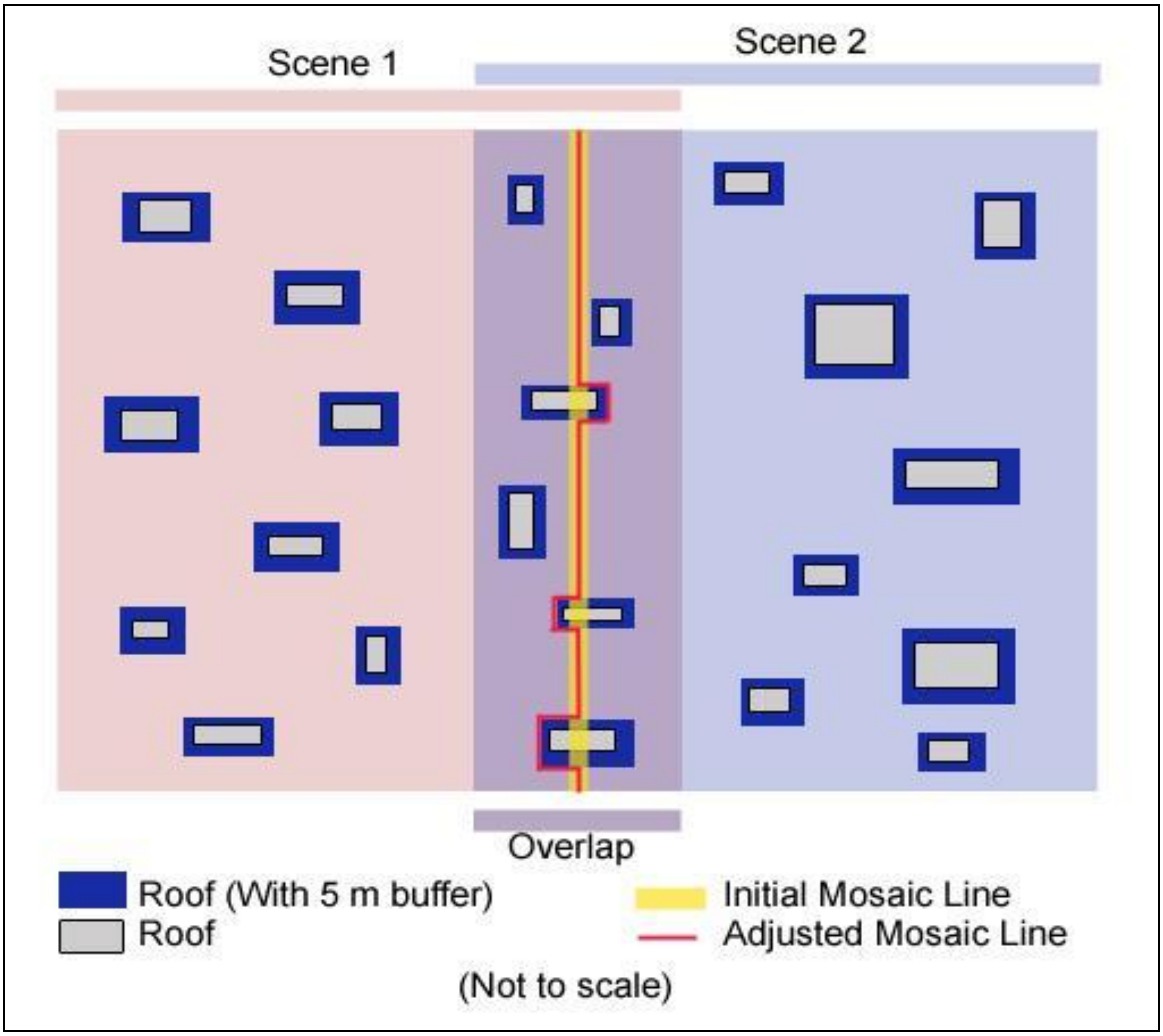


Fig 2. This image shows two flight lines (pink and blue) and their 30% overlap (purple). The yellow line represents the center (line) of this overlap. Roofs are shown in grey, surrounded by a blue spatial buffer. A new 'adjusted' mosaic line (red) is created from a joining of the center-line and the buffered roof objects. By using this adjusted mosaic line, roofs are never bisected.

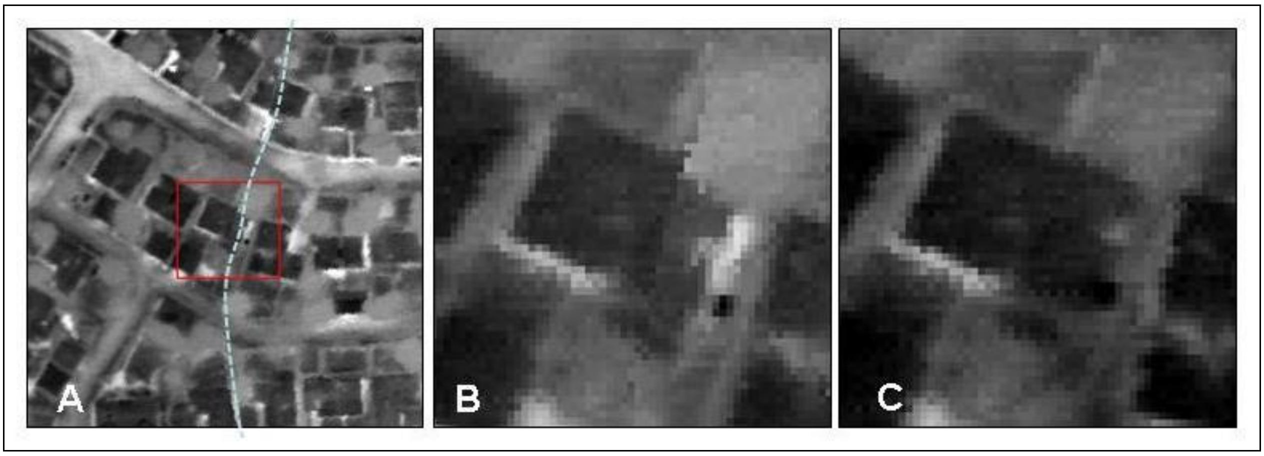


Fig 3. Figure (A) shows a sub-section of a TABI 1800 thermal mosaic (dark tones are cold, bright tones are hot), where the dashed line represents the mosaic boundary. The red inset box represents the zoomed area illustrated in the proceeding figures. Figure (B) shows a house that is bifurcated as a result of joining flight lines using a traditional pixel-based mosaicing algorithm. Figure (C) shows the same building resulting from OBM.

4. RESULTS AND DISCUSSIONS

Our Object-Based Mosaic (OBM) results visually demonstrate improved roof structure over the same roof-objects located in the mosaiced thermal scene provided by the vendor using a traditional mosaicing algorithm (Figure 3). It is observed that a roof bifurcated by traditional mosaic (Figure 3B) line results in distortion of shape, size, and thermal signature where as an almost appropriate shape and identical thermal pattern is retained by an OBM joined roof (Figure 3C).

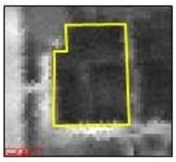
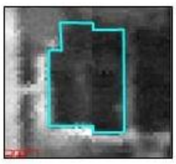
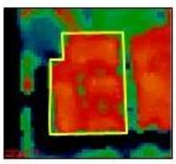
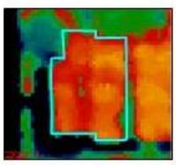
	OBM	Traditional
Figure (B/W)		
Figure (Color)		
Size	147.25 Sq m	142.7
Shape	Original	Distorted
Min Temp	-3.79	-4.04
Max Temp	-2.16	-2.11
Mean Temp	-3.38	-3.51
Standard Deviation	0.22	0.25

Fig 4. A statistical comparison between an OBM joined roof and a traditional mosaic joined roof. In the B/W figure, bright pixels represent high temperature and dark pixels represent low temperature. In the color figures, black pixels indicates high temperature followed by blue, green, yellow and red (low temp)

Figure 4 provides a statistical comparison between an OBM joined roof and a traditional mosaic joined roof. The b/w figures (Figure 4 Row 1) demonstrates the distorted shape of a traditional mosaic joined roof compared to a regular shape represented by OBM joined roof. The color figures (Figure 4 Row 2) and the minimum/maximum temperatures indicate more temperature variability (represented by shades of yellow, green, and red) in the traditional mosaiced roof than the OBM joined roof. Thus, less temperature variability, followed by low standard deviation indicates uniform temperature distribution over the OBM joined houses. This leads to improved hot-spot detection and more accurate TIR image based home energy models.

5. CONCLUSIONS

We describe a novel Object-Based Mosaicing (OBM) technique that represents a new geospatial method for mosaicing thermal flight lines that prevents individual house-objects from being bisected during the mosaicing process. This results in (i) visibly improved building structures within the scene, (ii) improved hot-spot detection and (iii) more accurately derived energy models as each roof-object is from a single acquisition time. In this research, we describe a GEOBIA application applied to roof-objects defined in H-res thermal imagery and suggest that this method may be applied to any defined objects of interest imaged in any wavelength, as long as the object(s) can be sufficiently defined within the scene.

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